JOURNAL OF THE A·I·E·E·

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
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American Institute of Electrical Engineers

COMING MEETINGS

Annual Convention, Edgewater Beach, Chicago, Ill., June 23-27

Pacific Coast Convention, Pasadena, Cal., October 13-17

MEETINGS OF OTHER SOCIETIES

National Electric Light Association, Atlantic City, N. J., May 19-23

Society for the Promotion of Engineering Education, Boulder, Col., June 25-26

The American Society of Mechanical Engineers, Cleveland, Ohio, May 26-29

Pacific Coast Electrical Association, San Diego, Cal., May 17-20. Coronado, Cal., June 17-20

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Vol. XLIII — MAY, 1924 — Number 5

TABLE OF CONTENTS

Papers, Discussions, Reports, Etc.

Institute and Related Activities

Current Electrical Articles Published by Other Societies

American Welding Society, March, 1924

Arc Welding of Non-Ferrous Metals—Symposium Fusion Welding of Aluminum, by C. F. Nagle, Jr.

American Electrochemical Society, April, 1924

Recent Progress in Electroplating and Electroforming, by W. Blum

Electrochemical Oxidation of Aromatic Hydrocarbons, by Fr. Fichter

The Measurement of Decomposition Potentials, by Alfred L. Ferguson and Gerrit Van Zyl

The Physical Review

Electrical Resistance and Thermo-Electric Power of the Alkali Metals, by Charles C. Bidwell.

Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

Vol. XLIII MAY, 1924 Number 5

Oil-Circuit-Breaker Ratings and Tests being Defined by Subcommittee

Among the important subjects which the Subcommittee on Oil Circuit Breakers is considering at the present time are the following: (1) Definitions of interrupting rating; (2) Specifications for testing oil circuit breakers; (3) Data on fuse tests, and (4) Tests of air-break disconnecting switches.

With two amendments the subcommittee has approved the suggested definitions of interrupting ratings proposed by the Oil Circuit Breaker Subcommittee of the National Electric Light Association, December, 1923. These definitions relate to value of current interrupted, operating duty and cycle, and required performance under test. The two amendments mentioned refer to an alteration in the definition of operating duty and to a recommendation that the Standards Committee define the r. m. s. value of a transient. The definitions will now go before a "committee on wording" consisting of representatives of the A. I. E. E., the N. E. L. A. and the Electric Power Club before presentation to the Standards Committee.

A preliminary draft of specifications for the testing of oil circuit breakers has been drawn up and is being circulated in the subcommittee for consideration and comment. This draft suggests specifications for the following subjects relating to oil-circuit-breaker tests: (1) System set-up and preliminary calculation, (2) layout of the test circuit, (3) test schedule, (4) test organization, (5) data sheet, (6) report and (7) test apparatus. All of these topics are outlined in detail in the draft.

Northeastern District to Hold New Form of Meeting

An important step towards increasing the value of the Institute to its members has been taken by the Northeastern District in planning the District convention which will be held at Worcester, Mass., on June 5 and 6. This meeting is being arranged by the combined Sections of this District under the leadership of the District Vice-president. An attractive program has been scheduled including three technical sessions, as well as special addresses and also inspection visits. (The full program is given on page 469 of this issue.)

The evident advantages of such a meeting are many. In the first place, it will furnish an opportunity for many members of neighboring Sections to become acquainted with each other. Such personal acquaintanceship among members will increase interest in the Institute. Secondly, many members can attend such a meeting who often find it impossible to attend a national convention at a greater distance. Thirdly, papers may be chosen for presentation which are particularly suitable for the district in which the meeting is being held. Fourthly, though papers of the very highest grade should be presented and by authors from any point of the country, the District meeting is an excellent place for developing young authors and for presentation of papers for the "First-Paper Prize."

Another advantage of such a meeting is that considerable time may be allowed for presenting each paper and also for discussion which is of great value both to the author and to the audience.

Still another good feature which will result from the holding of such meetings is that they will insure the presentation of much excellent engineering material which might not otherwise be offered to the members. Papers may thus be presented and thoroughly discussed which otherwise might never come before an audience, on account of the impossibility of finding a place on national convention programs for all of the great amount of material which is available.

As a last word, it might be well to say again that the Northeastern District should be congratulated on taking the initiative in arranging this new type of meeting.

Technical Committees' Annual Reports to be Published in Journal

At a recent meeting of the Publication Committee it was agreed that the annual reports of the Technical Committees should be given as wide publicity as possible, in order that members of the Institute may keep informed regarding the state of the art in the different branches of electrical engineering. In line with this agreement, it was decided that hereafter technical committee reports will be published in full in the JOURNAL. It was further agreed that in case of a large surplus of material available for publication, these technical committee reports shall be placed upon a preferred list in order that they will certainly be published.

Some Leaders of the A. I. E. E.

T. Commerford Martin, the third and senior surviving ex-President of the A. I. E. E., was born in London, England, July 22, 1856. Owing to the relations of his father to the pioneer submarine cable industry, the boy had the unique experience of visiting the old "Great Eastern" as a playground, of using little cable sections for toys, and of making the early acquaintance of Prof. William Thomson, on the famous steamship. The intimate friendship thus begun with Lord Kelvin lasted over fifty years, through correspondence and with frequent renewals. Mr. Martin represented the Institute and three other American societies at the Kelvin Jubilee in 1896 at Glasgow University.

Educated as a theological student, Mr. Martin found the attractions of physics quite irresistible, and with letters to such men as Cyrus Field came to the United States in 1877. He entered Edison's service at once, and both at Menlo Park and in the Edison-Bergman shops in New York had much to do with famous inventions, writing many articles in the New York papers on them, notably the telephone, microphone and phonograph. With health broken by the incessant work, he resigned in 1879 and went to the West Indies. After journalistic ventures and work for the Government of Jamaica, reporting on cinchona cultivation, etc. he returned, with health restored, to New York in 1880. He began immediately to edit the *Operator;* and in 1883, as one of the editors of the allied *Electrical World,* put to press its first issue. He remained as an editor of that journal and its components for 26 years.

In 1909 he was elected Secretary of the National Electric Light Association, which he helped to found in 1885. On account of impaired health, he resigned in 1919, becoming Advisory Secretary. In 1923 he took on the Secretaryship of the New York Electrical Society, of which he was President in 1900.

Mr. Martin was not only very active in 1884 as a founder of the A. I. E. E. and Secretary, but he has filled all save one of the elective offices. He was chosen its head in 1887, at the age of 30, being the youngest man to have held the presidency in any one of the four great national engineering societies.

Calling the attention of his friend in 1900 to the proposed sale of the Lattimer Clark library in London, Mr. Martin cabled for Dr. Wheeler the purchase of it. An Institute Library dinner was given in celebration in 1903; and Mr. Martin, after four efforts induced Dr. Carnegie to come to it. The famous gift of $1,500,000 for the United Engineering Society building and the Engineer's Club followed swiftly. He served for four years on the two Building Committees, and as President opened the new Club House with Dr. Carnegie in 1907.

He has contributed to all the leading American encyclopaedias and magazines, and is the author of numerous electrical books, including the first American history of the electric motor and its applications. As Special Electrical Expert for the U. S. Census office for 15 years, 1900-15, his reports are the first available in any country relating to the vast range of electrical industries and utilities. He has lectured in England and France and at a score of American colleges, serving also the New York Board of Education for a decade. He is one of the founders of the American Museum of Safety and of the Illuminating Engineering Society.

Lightning-Arrester Requirements and Specifications being Studied

The Subcommittee on Lightning Arresters has been working during the last few months towards formulating definite statements regarding the desirable requirements and the classification of lightning arresters. Already a subcommittee report termed "An Analytical Study of Lightning-Arrester Performance" is nearing completion. This study will be the joint opinion of the members of the subcommittee based on performance and test data. In the preliminary form in which this was circulated among the members of the subcommittee, it presented a brief description of the physical conception of the action of a lightning arrester in the most general case and arrived at the conclusion that the important points in which it is desirable to improve lightning arresters are:

1. Reducing the voltage of the initial breakdown.
2. Reducing the dielectric spark lag.
3. Reducing the impedance of the arrester.

This preliminary statement will be enlarged and revised and when completed will be used as a preamble or general statement on which may be based more complete description, specification and standardization.

The work of the committee will then be concentrated on outlining specifically the requirements of lightning arresters on given types of circuits and a proposed definite classification of lighting arresters.

Blind Soldiers as Telephone Operators

World Power, an English publication, contained in a recent issue a very interesting article on the success of teaching blind soldiers to operate a telephone switch board. A large number of these men after being trained has secured positions with large and well-known firms throughout the British Isles. According to their employers, the men have proved entirely capable and in some cases, the boards were operated even more efficiently than formerly.

At the present time there are several blind ex-soldiers awaiting an opening and organizations in England which are in need of such service are urged to consider these men. Their employment would not only be an advantage to the firm, but it would be helping these men to a useful and self-supporting occupation.

Automatic Substations for Industrial Plants

BY CHESTER LICHTENBERG
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Review of the Subject.—*Industrial enterprises have been the last to take advantage of the developments in automatic station equipment. As an aid to the engineers responsible for these establishments, the author has described the principal types of electric-power transforming equipment to which automatic switching has been applied. The automatic control of synchronous condensers, synchronous motor-generators, synchronous converters, synchronous hydroelectric generators and feeders is treated in such a manner as to furnish industrial engineers with data upon which to base the designs of automatic stations for factories, mills, mines, shops and other kinds of industrial power supply.*

* * * * *

THE automatic electric power station is a new development in the art. It was conceived by a central station engineer and developed by a railway engineer. It is natural, therefore, for automatic stations to be more widely used in these branches of the electric art than in industrial power applications. Nevertheless, the most promising field for automatic substations seems to be for the transformation and supply of electric power for all sorts of industrial purposes.

Electricity supply for factories, mills, mines shops and other industrial enterprises usually lends itself quite readily to automatic operation. The kind of automatic switching equipment and its application, however, depends to a large extent on the particular requirements of the industry served.

Generally, some form of power-transforming equipment is utilized for these enterprises. It may be rotating equipment such as motor generators, synchronous converters or synchronous condensers, or it may be static equipment such as transformers, static condensers or mercury tube converters. All of these have been equipped with automatic switching and control for central station and railway service and can readily be adapted to electrified industrials.

Primary power plants where water is the source are particularly well-suited for automatic control, but steam-operated stations have not yet been added to the rapidly growing list of automatic station installations.

Synchronous condensers form one of the simplest classes of rotating machines to which automatic station control equipment has been applied. They also form a class of power conservers which industrial organizations seem hesitant to adopt. It may be that heretofore the need to provide them with an operator has retarded their location at strategic points on the power network, or forced their location in existing attended stations which were remote from the preferred point for best performance. Whatever the reason may have been, the successful automatic operation of these units has very widely extended their field of application, particularly to electrified industries.

The first automatic synchronous condenser was a 3000-kv-a. unit installed by the Interstate Light & Heat Company at Hazel Green, Wisconsin. It was started in March, 1917, and is still in successful operation. It is located at a point on the power company's transmission lines where regulation had previously been quite poor. It more than paid for its cost in the first two years' operation. The latest automatic synchronous condenser is a 7500-kv-a. unit being installed by the New England Power Company at the Worcester, Mass. mills of the American Steel and Wire Company. In the meantime there have been a number of installations of automatic synchronous condensers but invariably by the power companies, although in most cases the condensers have been utilized for the correction of power-factor conditions caused by the industrial enterprises using the electricity.

The automatic control of a synchronous condenser is relatively simple. The starting impulse is given by any one of several familiar devices. A voltage relay, a power-factor relay, a time clock or simple tumbler switch may be used to start the set. The synchronous condenser is usually provided with an amortisseur winding and is brought up to speed as an induction motor. A compensator or Y-delta starting scheme may be used, either being readily adapted to automatic control. Usually during the period of acceleration, the synchronous condenser field remains disconnected from the source of exciting current and is bridged by a field-discharge resistor. This aids in giving the required starting and pull-in torque. After its field is excited, the unit has been connected to the line and full pressure applied to its windings, it begins to function as a power-factor corrector. A power-factor regulator or a voltage regulator which forms part of the automatic switching equipment adjusts the field current automatically to maintain either fixed power factor or fixed pressure within the limits of operation of the unit.

Automatic synchronous condensers are provided with the usual automatic station protective devices. The bearings are equipped with bearing temperature relays which will cause the set to be shut down if the bearings tend to overheat and before damage results. The machine armature is provided with current-operated thermal relays having a time-temperature characteristic similar to that of the condenser. These automatically shut the machine down if the armature current exceeds a safe value for a given time. They also permit the unit to re-start automatically after a shut-down of a sufficient time duration to cool the windings. These

Presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924.

thermal devices are of the integrating type and are self-adjusting for ambient temperatures. A grounding protective relay is also provided which causes the set to shut down in case of any leakage to ground in excess of 50 amperes. This cares for any insulation failures and prevents undue damage. Single-phase starting, harmful single-phase running, reverse phase, loss of field, too low line pressure, short time a-c. overload, etc., are also cared for by the usual automatic station relays.

Synchronous motor generators form the next general class of rotating electrical machines which have been successfully equipped with automatic switching. Units of 150 kw. in capacity are now operating in many sections of the coal mining district and are typical of the smaller sizes. A 2000-kw. set is in operation on the 666-volt d-c. electrification on the main line of the New York Central Railroad and is typical of the larger sizes applied to very severe operating conditions. These units may be started on load demand or at a pre-determined time or by a tumbler switch or its equivalent. The automatic switching equipment proceeds to function immediately the starting impulse is given. First, it checks the line pressure to be sure it is ample to start and run the set. Next, it checks the supply to be sure all the phases are intact and are of the correct sequence. Then, it checks the bearings, machine windings, and ambinet temperatures, to be sure

Fig. 1—United Railways of St. Louis, Franklin Ave. Substation, St. Louis, Mo. for Synchronous Converter 600-Volts, 2-Kw. 25-Cycle 6-Phase and Portion of 6 Stub End and Multiple D-C. Reclosing Feeders 600-Volts 2000-Amperes for Reclosing from Either Side

these will permit the machines to run if and when started. Next, it connects the motor to the source of power, either through a compensator or to taps on the transformer, or through the transformers direct if Y-delta starting is used. Then the set starts to rotate and increases in speed. At synchronous speed, the automatic switching equipment again takes hold and connects the field circuit to the source of the exciting current. When field current has been established, the set is transferred from the starting combination to the running combination. During the accelerating period the motor field remains disconnected from the source of exciting current and is bridged by a resistor in the same manner as is the synchronous condenser during its starting cycle. This permits individual adjustment of each motor so as to obtain a complete start under practically all conditions which can be found in service.

In the larger sets, a low value of field is applied while on the starting tap, and the final value after the machine is transferred to the running connections. In the

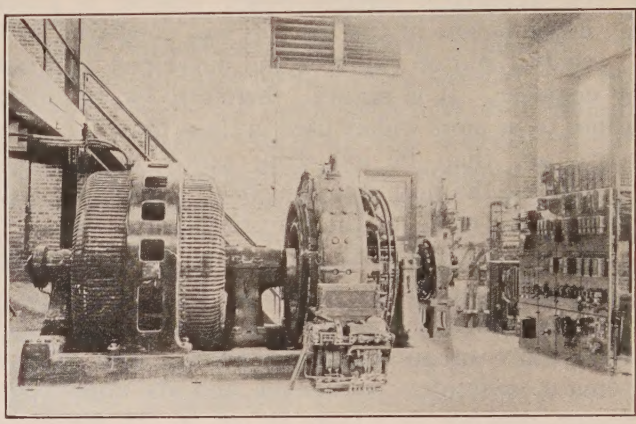

Fig. 2—Automatic Railway Substation, New York Central Railroad Co. 110th St. General View of Station Showing 2000-Kw. Motor-Generator, High Speed Circuit Breaker and Automatic Control Panels

smaller sets, the final value is applied in one step while on the starting tap. The smaller sets having 250-volt or 275-volt generators are usually excited directly from the generators. Those rated for higher pressures or arranged with voltage regulators are usually fed from an exciter either separately operated or direct connected.

The synchronous motor has the usual automatic station protection to prevent runaway, operation without field, harmful single-phase operation, leakage to ground, short-time and long-time continued overload, bearing temperature, etc. Some of these devices, such as the bearing temperature relays, are hand reset where continued operation of the machines under any circumstances might lead to their destruction. The number of such devices, however, is a minimum so as to insure continuity of service under all conditions, excepting where the machine might fail and thus interrupt such continuity for a long time. Most of the other protective devices, such as the long-time delay overload relays, phase-checking relays, etc., are automatically reset and permit the equipment to resume normal operation as soon as the unusual conditions have been corrected.

The d-c. generator is provided with protection and adjustment, depending upon the service requirements to which it will be subjected. The simpler equipments, which may be shunt or compound wound, are usually operated with a fixed shunt-field setting. This setting

is chosen to give the desired terminal pressure, and in the case of multiple-unit sets, must be carefully adjusted to give the correct loading of the machines. Multiple-unit stations also require careful compounding of the units to permit the successful multiple operation of "hot" and "cold" machines.

The d-c. generators of larger sized sets are frequently provided with automatic load regulation. One type is provided with a shunt-field bucking scheme. This has been successfully applied to shunt-wound generators for multiple-pressure booster service. The shunt-field current is normally furnished by the generator itself. The current is then passed through the armature of a tiny motor-generator continuously rotating. This set, by a suitable raising or lowering of its field current, bucks or boosts the shunt-field current of the generator the correct amount and gives the desired regulation. In one example, using this method of control, load swings of from 300 per cent normal to 200 per cent reversal are successfully handled.

Another modification is a compound-wound d-c. generator with the series field connected to oppose the shunt field. This type of generator is usually operated with the series field shunted by a circuit breaker which allows only a fraction of normal current to flow through the field when it is closed. Under heavy overload

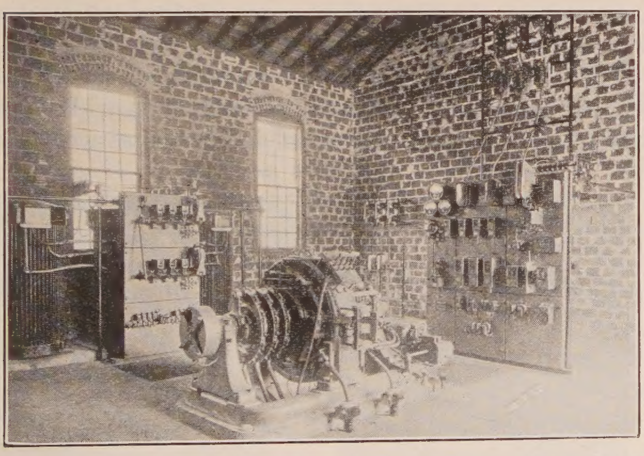

Fig. 3—Clearfield Bituminous Coal Corp., Grass Flat, Pa. Pleasant Hill Mine. Interior View of Station Showing Automatic Switching Equipment and Synchronous Converter 275-Volts 200-Kw. 6-Phase 60-Cycles and Combined Stub End and Multiple D-C. Reclosing Feeder 275-Volts 1090-Amperes

conditions, the circuit breaker is automatically opened and the series field carries the full line current. Under this condition it tends to oppose the shunt field. Now by suitably proportioning the shunt and series fields, the d-c. generator can be made practically a constant-current machine and service may be maintained at a reduced pressure during emergency load conditions. As soon as the overload condition ceases, the circuit breaker automatically recloses and shunts the series field. A number of such equipments is operating on the Edison three-wire networks of many of the large electricity supply corporations, and their use is being very rapidly extended. Their judicious application to electrified industrial establishments would insure continuity of service under the most severe conditions short of complete and sustained interruption of primary electricity power supply.

Synchronous converters form without exception the largest single class of rotating electrical machines which have been successfully provided with automatic switch-

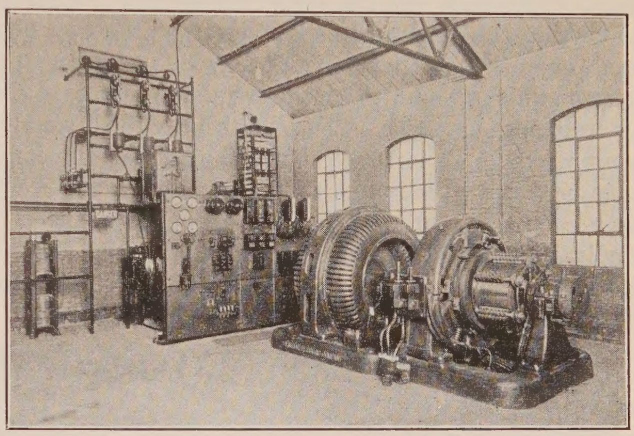

Fig. 4—300-Kw. 250/275-Volt D-C. 6000-Volt 3-Phase 60-Cycle Synchronous Motor-Generator with Automatic Control Equipment, Clearfield Bituminous Coal Corporation, Rossiter, Pa.

ing equipment. In fact, they were the first electrical machines to be so equipped, notwithstanding the fact that with a single exception they are considered the most difficult electrical machines to operate. This is principally because of the almost universal application of synchronous converters for interurban railway service where automatic stations were first widely adopted.

The automatic switching and control of synchronous converters assumes the a-c. supply to be available before any starting operations are performed. Consequently, all automatically-controlled synchronous converters are invariably a-c. starting. Also, with one or two minor exceptions, the starting is accomplished with the aid of an amortisseur winding on the field.

The starting indication for an automatic synchronous converter may be any one of the usual devices, such as a pressure relay, a time switch, a tumbler switch, or their equivalent. Immediately the starting impulse has been completed, the synchronous converter is connected to the starting taps on the power transformer. One-third taps or one-half taps, depending on the design of the synchronous converter and transformers, will usually furnish sufficient torque to start the converter armature and pull it into step. Then the converter is automatically transferred from the starting taps to the running taps.

During the starting operation, the shunt field is usually opened. After the machine has reached syn-

chronous speed, its field is either flashed with the correct polarity before it is made self-exciting, or its field is reversed until correct polarity is established.

The next step in the process is to connect the synchronous converter to the d-c. network or feeder, and here the inherent characteristics of the converter require a different series of operations than do motor-generator sets. The d-c. terminal pressure of a synchronous converter is regulated largely by the a-c. pressure-supply. Only a relatively narrow range of d-c. terminal-pressure adjustment is possible by field adjustment. This then requires some arrangement for safely connecting the synchronous converter to the d-c. network, even though that network may be operating at a pressure quite different from the terminal pressure of the synchronous converter. This condition is most usually encountered in all sorts of electric haulage installations, since here the wide swings in power demand are very large compared with the feeding capacity of the a-c. supply. For electric railways and commercial electric power service generally, and sometimes for industrial

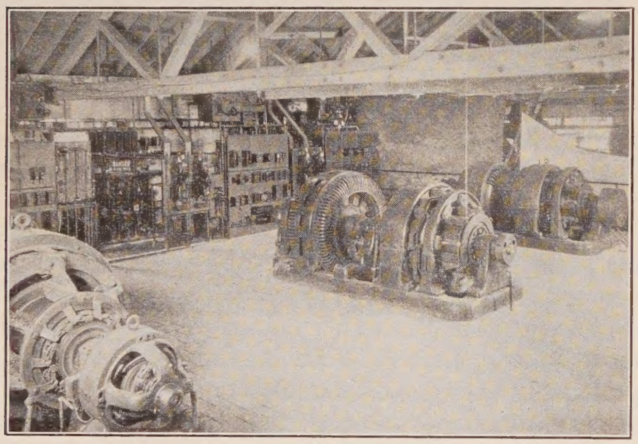

Fig. 5—Automatic Station Control Equipment, Mobile Electric Company, Mobile, Alabama. Synchronous Motor Generator Set and Control Equipment

electric power supply, synchronous converters are equipped with load-limiting resistors. These are connected between the d-c. terminals of the synchronous converter and the d-c. network or feeder after the synchronous converter has been placed in complete running condition insofar as the a-c. side is concerned. These resistors are then usually shunted out in two or three steps thus gradually loading the synchronous converter from the d-c. network. The shunting contactors or circuit breakers used for this service are usually provided with current relays having interlocks so that the synchronous converter cannot be loaded beyond its thermal capacity. Other devices such as thermostats, located near the load-limiting resistors, permit the synchronous converter to supply current to the d-c. system within safe heating limits until the load is reduced or the resistors and converter tend to dangerously overheat. Under these conditions, the converter is automatically shut down until it and the resistors cool. After the equipment has cooled sufficiently, a fresh start is automatically made. In some cases the load-limiting resistors are shunted out in only one step where economy in design and manufacture permit Y-delta starting. With this combination and with suitable

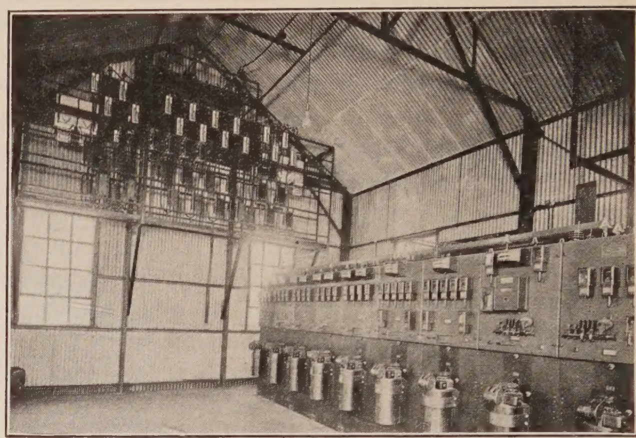

Fig. 6—Long Island Lighting Co., Port Washington, L. I. Outgoing Lines and Portion of Automatic Switching Equipment for Five 2-Phase and Two Single-Phase 2200-Volts 60-Cycle Reclosing Feeders abd Transfer Apparatus for Two Incoming Lines

transformer design, the Y-delta arrangement may be used to take the place of one step of the load-limiting resistors.

The load-limiting combination available for, and used with, synchronous converters permits their wide application to all sorts of electrified industries as well as to

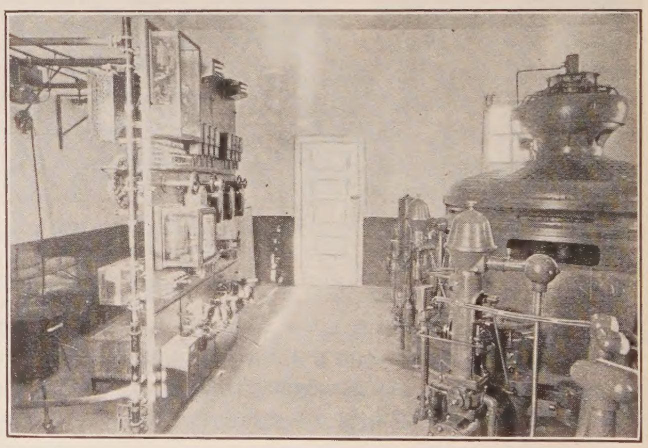

Fig. 7—Automatic Generating Station Control Board and Generator. Fairbury Mill and Elevator Company. Two 40 150-Kv-a. 180 Rev. Per Min. 2300-Volt Generators

electric railway and electric power supply systems. It permits the use of the economical synchronous converter in many places where motor-generator sets were formerly considered supreme. For certain few applications, they are excelled only by specially designed motor-generators with automatic load-regulating features.

Synchronous converters for automatic operation are provided with the usual automatic station protective features such as bearing and resistor temperature relays, short and long-time continued a-c. overload relays, single-phase starting preventive and harmful continued single-phase running preventive relays, low a-c. pressure starting or operating preventive relays, overspeed switches in combination with a shunt trip circuit breaker, leakage to ground relays, etc.

Other electric power-transforming machines, such as balancers, mercury tube converters, and static transformers have been made completely automatic and are now in successful operation. Their design usually takes pattern after the best manual operation scheme, except that the time for the switching is generally reduced from a matter of minutes to a matter of seconds.

The automatic hydroelectric plant is one of the outstanding applications of automatic switching equipment to industrial enterprises. Consider, for example, the many streams of moderate size but relatively uniform flow which are found in the upper Middle West. They have been used for many generations to drive grist mills of quite good size, as well as performing many other industrial functions of varied natures. The hydro equipment which has heretofore been used is fast becoming antiquated and the output of the mills is suffering in consequence. The recent installation of automatic hydroelectric equipments in a number of these mills has wrought an important change in this section of the country. The same streams now permit not only a greater mill output in combination with the electrification of the mills, but also provide an inexpensive power supply to adjacent towns and villages. More important even is the fact that the electrified mill can now be connected to the large electric power supply system covering the country, and can either take power from this system during times of low water or can feed power into the network during times of high water.

Automatic hydroelectric stations almost invariably use synchronous generators since they can be provided with their own exciters. They almost always have a waterwheel equipped with either an oil pressure governor, a servo-motor, or motor-operated gates. The synchronous generator is usually provided with an amortisseur winding to assist in pulling the machine into step. The starting impulse is given by any one of the familiar relays or by a push button, or may be given by making alive the station feeder from an a-c. network. Immediately after the starting impulse is completed, the waterwheel gates are opened and the waterwheel started. Then the gates are shut until only enough water passes through to bring the machine up to about 95 per cent normal speed. At this point the armature is connected to the a-c. network, either directly or through transformers and immediately thereafter the field is excited. This brings the generator into phase with the network and places load on the machine.

Automatic hydroelectric stations are usually provided with automatic voltage regulators and these, in combination with the hydraulic regulating equipment, adjust and maintain the desired load on the equipment.

Automatic hydroelectric stations are provided with only such protective features as are needed for the quite simple machinery involved. Excess speed, excess electric pressure, insufficient oil pressure, bearing and machine heating, short and long-time, continued overloads, together with loss of field, each has its protective devices, which make the automatic hydroelectric station economical and safe in sizes up to 8,000 or 10,000 kw.

Feeders for a-c. and d-c. networks and supply are now not only automatic tripping on overload, but also automatic reclosing. Many forms are available, each being particularly designed for its individual application.

REVISION OF CODE FOR ELECTRIC METERS

The Code for Electric Meters, approved as an American Standard by the A. E. S. C. in 1922, covers many phases of electric metering practise. It includes specifications for the test and acceptance of types of watthour and demand meters with their accessory devices, such as current and voltage transformers and shunts, and recommendations on installation, maintenance, and meter testing methods. This code is the basis of American practise in the manufacture of electricity meters, and their use, test, and maintenance by public utility operators. Approval tests of types of meters by public utility commissions are based on the code, and the rules for periodic meter testing formulated by state commissions are in accordance with its general provisions.

Revision of this Code is being made by a sectional committee under the joint sponsorship of the Bureau of Standards, the Association of Edison Illuminating Companies, and the National Electric Light Association, in accordance with the procedure of the A. E. S. C. The sectional committee consists of 18 members, six representing manufacturers of electricity meters, six representing users, and six representing the general public. The sectional committee has been organized under the chairmanship of a member of the staff of the Bureau of Standards, while the secretary is an engineer of the Electrical Testing Laboratories. Four subcommittees have been formed to prepare the draft of the revision under the general direction of the sectional committee. The subcomittees include among their members many meter engineers of manufacturers, central-station operators, and engineers from research and university laboratories.

An Experimental Study of Ventilation of Turbo Alternators

BY CARL J. FECHHEIMER[1]

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When designing a large steam turbine-driven alternator, the volume of air per minute needed to cool the machine may easily be calculated after having estimated the losses and after having decided upon the value of the temperature increase of the air while passing through the machine. The pressure delivered by the generator thereof, (the fan) can be predicted with reasonable accuracy from data to appear in an early paper[2]. On the other hand the distribution of the air, and the pressure needed to drive it through the various paths are too difficult to predict with our present knowledge of the laws governing the flow of air. In any of the recognized systems of ventilation, there are combinations of various series and multiple paths, and in practically each path there are changes in direction or section, and at each change there is a loss of head. In order to design large generators intelligently, it is important to predict what the quantitative relations are within a reasonable percentage of error. The only feasible way to determine them at present is by means of experiment, and that, too, becomes involved.

In general, a complete machine is not suitable for an experimental study of air flow, as changes in the series or parallel paths, the introduction of restrictions, etc., can be made only with difficulty, delays and expense. It was recognized that much of the best work in aeronautics was done experimentally, on models. Accordingly, it was decided, in the early part of 1920, to build two models to imitate two radial systems of ventilation. Since ventilation, as such, was to be investigated, no electrical nor magnetic losses were to be introduced. The peripheral velocity of the rotating element should be not less than that of a large generator. The construction of the rotor was to be similar, in so far as ventilation was concerned, to that of the largest generators. The length should correspond to about half the length of the probable longest rotor in a machine having the same diameter as the rotor of the model: (half the length, because it was considered desirable to imitate only one-half the machine longitudinally, as the other half would be duplicate in inverse order). The packages of laminations in the stator were to be imitated by rings of hard wood into which slots of standard size were to be cut; between adjacent wooden rings standard vent spacers were to be placed; wood could be used to imitate the coils at the vents, etc. An external blower was to be used, chiefly because the delivered air pressure would be independent of the rotational speed, but also because the static pressure could be measured in a quiet zone where the velocity head was of negligible influence. The whole was to be so made that a maximum of flexibility was to be obtained. Thus, the use of wood in the stator permitted of rapid and inexpensive alterations; steel rings placed over the entrances to the longitudinal vents in the rotor would stop its supply of air, as desired; the entrance to the air gap could be closed by means of a suitable angle ring; the entrances to the stator could be open or closed; several sizes of air gaps were to be used; various restrictions in the air circuit were to be introduced; etc. Thereby, data on the flow in any individual air circuit, such as the stator, the rotor, or the air gap, etc., or a combination, at various air presures and at various rotational speeds, could be obtained and the results studied.

1. End Bell and Pressure Measurements

The outer part of an existing cast iron end bell was bolted to one end of the model;[3] it was split, so that half of it could be readily removed for alterations. With the end bell parting horizontal, the upper half could be readily removed. The intake duct was easily attached. The velocities of air in parts of the end bell were so low that an ordinary open-end brass tube could be used for connecting with a manometer for measuring pressures without introducing an appreciable error due to velocity head. The tube was pushed through a sealed wooden plug fastened into one of the upper bolt holes in the end bell. Pressure readings were also taken near the parting farthest from the entrance to the end bell; there the velocities were substantially zero and the pressure readings were practically the same as in the other location.

2. Diverging Intake to End Bells

The outlet of the blower was 18 in. square, (2.25 sq. ft.) and the cross-sectional area of the end bell at its entrance was a little more than four times as great. In the second model, volumes approximating 15,000 cu. ft. per min. were admitted to the end bell, in certain cases. This corresponds to a velocity of 6660 ft. per min., at discharge from the blower, or a

1. The author was assisted by Mr. Donald Bratt, who is contributing a companion, mathematical, paper to the Institute.

2. "Performance of Centrifugal Fans for Electrical Machinery." To be presented before the American Society of Mechanical Engineers.

Abridgement of paper presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 8, 1924. Complete paper available without charge to members upon request.

3. The lower half of the end bell attached to Model 2 appears in Fig. 12.

velocity head of 2.73 inches of water. In that case, the static pressure in the end bell was only 3.3 inches of water, and the velocity head there was only $(\frac{1}{4})^2 \times 2.73 = 0.17$ inches of water. It would not have been feasible to secure that delivery from the particular blower unless a considerable percentage of the velocity head at its discharge were converted into static pressure. It is well known that to recover the maximum velocity head in a comparatively short length, the duct should be shaped like a trumpet with curved sides, and that was the form that was adopted; that intake is shown in Figs. 4 and 12.

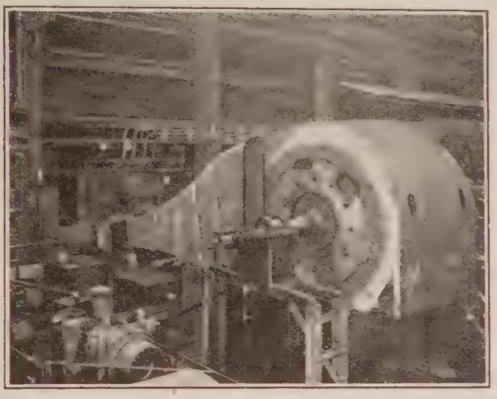

Fig. 4

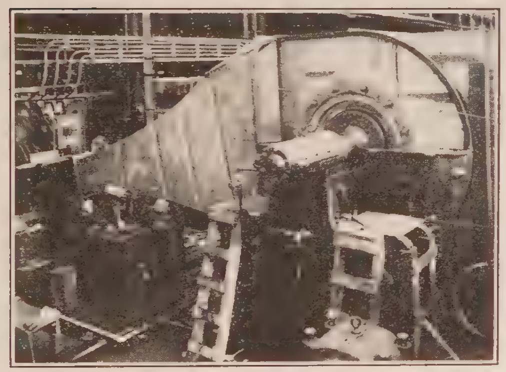

Fig. 12

3. Volume Measurement

The volume of flow was measured by the thermal principle which Prof. Carl Thomas introduced. The air was heated by causing electric current to flow through a suitable resistor in the air stream, the power consumed being measured by familiar indicating electrical instruments. In the Thomas meter, the temperature rise of air is measured by means of coils in the air stream before and after the air passes through the heater, these exploring coils being connected in a Wheatstone Bridge network. Previous experience showed that those coils were not entirely satisfactory for this kind of work, as the wires were likely to stretch; also with the large volumes, the temperature rises would be too low to obtain accuracy, unless the power consumption in the heater were prohibitive. These objections were overcome by connecting numbers of thermocouples in series; then a comparatively high reading of millivolts on a suitable potentiometer secured accuracy with the low air temperature rise of, say 1.5 to 3.5 deg. centigrade.[4]

4. Volume Distribution

Both models were provided with radial vent ducts, in some of which the air passed radially inward, and in others, outward. It was desired to measure volumes (or velocities) in both. Attempts were made to measure the intake vent velocities in the first model by means of hot wire anemometers, but they were unsuccessful, because in the construction as used the indication is largely dependent upon the direction of flow.

The method used for measuring outlet duct volume-distribution was more successful. The vent duct finger spacers were made continuous to the rear, so that a given volume of air that entered a particular space between adjacent fingers would continue to flow to the rear. The fingers were spaced uniformly at the rear. A small "funnel" which just fit between adjacent fingers was joined to an ordinary rotating vane anemometer, which was held in position for half minute readings. The anemometer was calibrated at the laboratory with the funnel, and from readings, the volume of air per minute passing between adjacent fingers, could be determined by referring to the calibration curve. The sides of the part of the funnel that was inserted between fingers were tapered slightly, so that it could be pushed in tight. Putty was put around that part of the funnel to eliminate leakage, but the readings with and without the putty were substantially the same, so that the putty was subsequently omitted.[5]

The Systems of Ventilation

The simplest radial duct system of ventilation of turbo alternators is the one in which all the cooling air passes direct from the end bells into the two ends of the air gap. The air flows axially through the gap and passes outward through radial ducts distributed in the stator core. This system has been used successfully for many years and is used today for certain sizes and types of design. In some of the large turbos, particularly for 60 cycles, of proportions that are considered normal at the present time, it becomes difficult to cause enough cooling air to flow through the two paths in the air gap. The air-gap size should be based upon the armature ampere-turns; then it is too small to transmit the volume of air unless the velocities,

4. The volume meter will be seen in Fig. 4, where it joins the small end of the trumpet shaped diverging duct. The formula for computing the volume is given in the complete paper.

5. See complete paper for discussion of inaccuracies of the anemometer.

(and therefore the pressures) become prohibitively high, or unless the air temperature rises, in excess of that which is considered good practise. The solution then lies in providing additional paths.

If cooling air is admitted at both ends of the air gap, and additional intakes are to be provided, and the air in them is to pass radially throughout the depth of the vent duct, then the only feasible way for that air to enter is through selected vent ducts at the back of the core. The air then passes radially inward to the air gap, then turns through 90 deg., then passes through the gap, and finally turns again through a right angle flowing radially outward through other vent ducts. The air which flows from the back of the core radially inward may be constrained to pass circumferentially or axially through the gap. The mechanical construction is necessarily considerably different in the arrangement of connecting with the inlet and outlet vents for these two directions of flow in the gap. In the two experimental models the two directions of flow in the air gap were embodied; in model 1 the air flowed circumferentially, and in model 2 it flowed axially.

Construction of the Turbo Models

1. The Rotor

As the peripheral velocity of the rotor was to be at least 24,000 ft. per min., and as it was not considered advisable to exceed 3600 rev. per min., or thereabouts, the diameter was fixed at 26 in., corresponding to 24,500 ft. per min. at 3600 rev. per min. The length of the body of the probable longest rotor of that diameter was about 120 in., so about half that useful length was decided upon.[6]

The large Westinghouse turbo rotors are of plate construction with radial vent ducts at intervals: These vents are only around the slot portions, each plate being milled individually before assembly. That construction was adopted in the models. Air enters through slots below the main slots, the coils acting as fans. The slots were arranged in four groups to imitate four poles. As in the machines, the plates are held together by through bolts between stub-end forgings. The coils are imitated by treated hard wood blocks driven into the slots, held in position by wedges of the same size as in a machine of corresponding proportions. The influences of the coils at the ends, and of the retaining rings, upon the ventilation of the stator and of the rotor body, were negligible, so those parts were not imitated in the models.[7]

Construction of Model No. 1

The first model, Fig. 4, imitated the scheme of ventilation in which the air moved circumferentially in the air gap. The number of stator slots selected was 54, and the number of stator axial intakes or outlets was six. Then there were (54 / 6 =) 9 teeth in each combination of intake and outlet belts; as the outlet was to carry the intake air plus the air admitted direct from the end bell to the air gap, a larger number of teeth was placed in the outlets than in the inlets, five in each belt of the former, and four in the latter. Further, in order to assist in the study, the vents in the upper half were provided with two fingers per tooth, and in the lower, one was used. To simplify manufacture, a circle of existing punchings with vent fingers attached were nailed on one side of each wooden ring. Small wooden blocks, having the same width as the slot, the same depth as the slot below the wedge, and the same thickness as the vent duct width, were nailed to each wooded ring for the purpose of imitating the coils in the vent duct. In this model, short fiber wedges were screwed to the small wooden blocks. The large wooden rings had previously been

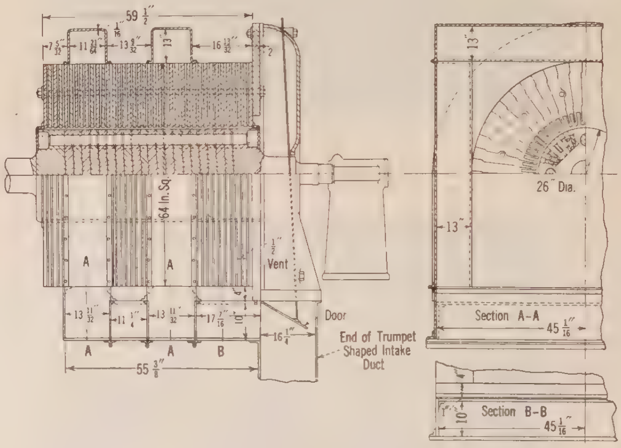

Fig. 10—Model for Investigating Ventilation of a Turbo-Alternator

slotted to the depth that the wedge is sunk below the inner periphery of the stator punchings in a machine. The composite in the tooth belt simulated that portion of a generator quite accurately.

An estimate of the velocities in the vent ducts back of the teeth indicated that the pressure drops there would be very small in comparison with the drops in the teeth, around the wedges, turning through a right angle etc. Consequently, the pressure needed for a given volume would be substantially the same if the length of the path in the vents back of the teeth were materially shortened. Recognizing this, the construction was considerably simplified by cutting out parts of the wooden rings and punchings at six equidistant places circumferentially, thereby providing ample area for the axial passage of the air from the end bell. (See Fig. 4)[8] (If the same system of ventilation

6. The rotor was made a little longer than the stator, in order that an angle iron, put in to stop the flow of air, could be placed over the extension.

7. The construction will be understood by referring to Fig. 10 in the complete paper.

8. In Fig. 4 some of the entrances to the intakes are closed and some are open.

were used in a machine, these axial passages would be incorporated in the frame.)

As will be seen from Fig. 4, an existing cast iron frame was used for the first model. This frame had "chimneys" at the top and bottom and they were so large that a man could climb into them and take anemometer observations at the outer peripheries of the wooden core. The stator of this model was shorter axially than the rotor. This was because the blower which was used was not capable of delivering more than

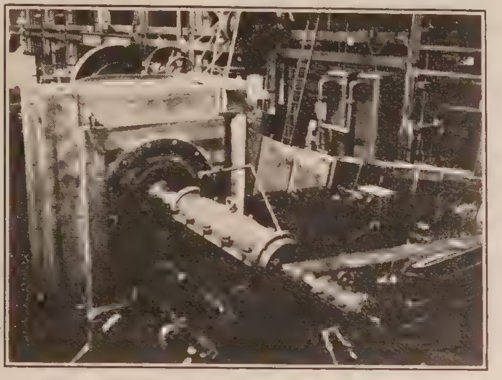

Fig. 13

10,000 cu. ft. per min at about 10 in. of water at its maximum safe speed; and the length of the stator was made such that its resistance to the flow of air would approximately correspond to those values. These figures were based upon a preliminary rough estimate of pressure drops. Owing to the direction of flow in the gap, in the first model, it was not so important to make the length about half of the probable maximum, as in the second model. On the other hand, it was important to secure fairly high end bell pressures, in order to determine the combination of pressures and peripheral velocities.

Construction of Model No. 2

The scheme of ventilation will be understood from an inspection of the upper part of Fig. 23, and from Figs. 12 and 13.[9] In this model, the frame casting was abandoned. The hard wood spacers which imitated the stator punchings were square on the outside, and circular with slots, teeth, etc., inside. The dimensions of the teeth and slots were the same as in model 1. The vent spacers were made, like in model 1, by fastening fingers to punchings, with slots spaced as for 54 per circle, the punchings being circular on the outside. Only single fingers were used; these were run to the backs of the punchings and were uniformly spaced there, to assist in volume distribution measurements.[10] Stator slot wedges were omitted in this model. The same method for imitating coils in the vent was adopted as in model 1, but the small wooden blocks which imitated the coils in the vents were made of such depth as to correspond to the coil plus the wedge; the wedge notches were absent. The stator was supported on suitable steel structure, so arranged as not to interfere with the flow of the discharged air, except at short distances from the corners of the square, where the velocities were very low; and the air which would have been discharged there was diverted without affecting the flow in the restricted sections in the teeth appreciably.

The door indicated in Fig. 23, and shown in Fig. 12 was employed to reduce the effect of a spiral eddy in the end bell which caused a high pressure drop; this whirl would be absent in a machine provided with internal fans.

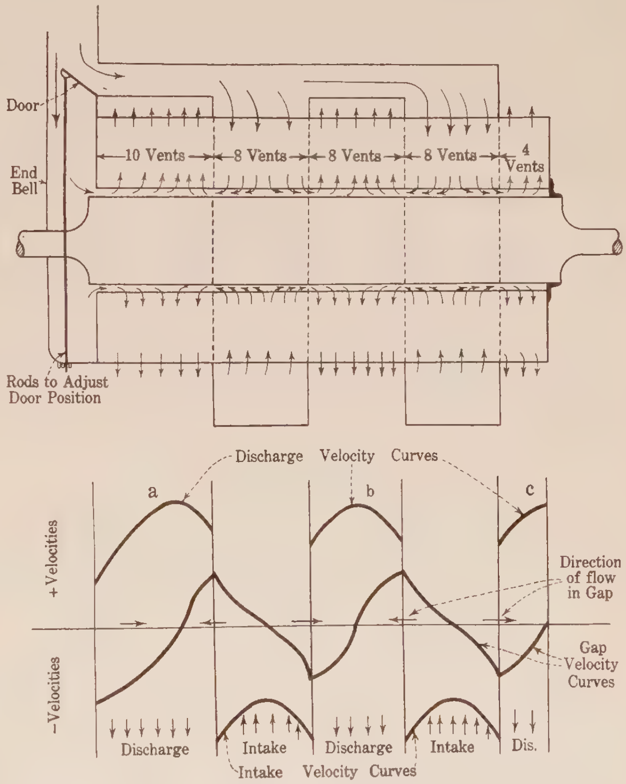

Fig. 23—Turbo Model No. 2 Schematic Diagram to Show Directions of Air Flow and Distribution of Volumes

Test Results

Only a few of the results that are representative are included in the complete paper. In this abstract they are again reduced in number, and a bare description is given herewith and only meager discussions are included. Many more tests were made on model 2 than on model 1.

Two curve sheets for model 1 are reproduced in Figs. 16 and 19. In both, all of the main stator intakes and the end bell entrance to the air gap were open, the rotor vents being closed. In Fig. 16 the influences of pressure and speed upon the volume will be seen at a

9. A drawing showing proportion is in the complete paper.

10. The anemometer readings were taken only between 3 to 5 adjacent fingers at the top and at one side, as others were not accessible.

glance. There is absolutely no question but that the volume is materially reduced with this scheme of ventilation, by an equivalent counter pressure due to rotation. At zero speed the volume is practically proportional to the square root of the pressure, but not so when the rotor revolves. The influence of rotation is greater, the lower the pressure.

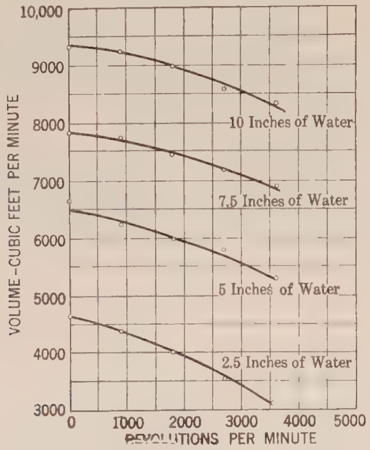

Fig. 16—Model I. Volumes for Various Rev. Per Min. and Static Pressures with Stator + Air Gap Open

In Fig. 19 the distribution of volumes for the single-finger vents is shown, outlet readings having been taken in four adjacent vents. They are plotted for zero and 3600 rev. per min. Ignoring various irregularities the following deductions may be drawn from Fig. 19:

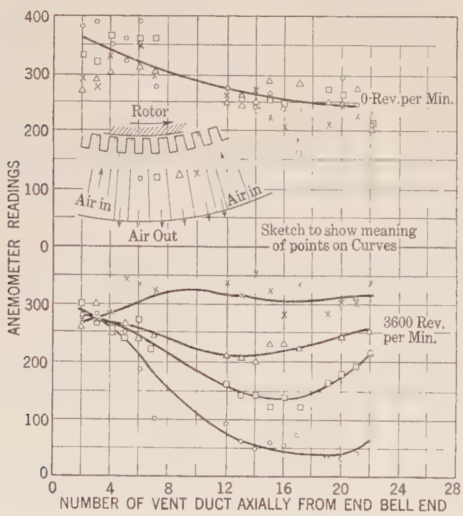

Fig. 19—Model I. Volume Distribution Curves Taken at Pressure of 7.5 in. of Water. Stator and Air Gap in Parallel

(a) At standstill there are no differences circumferentially, at a given distance axially.

(b) At standstill the volume discharged per inch axially decreases with the distance from the end bell entrance.

(c) At 3600 rev. per min., the circumferential distribution is substantially uniform near the end bell.

(d) At 3600 rev. per min., the circumferential distribution departs from uniformity as the distance from the end bell entrance increases, the distortion apparently reaching a maximum a little before the extremity[11].

(e) Considering that the air in the gap moves circumferentially in the same direction as the rotor surface moves, then, due to rotation, the velocities are decreased materially in the first vent ducts and are increased slightly in the last vent ducts with intermediate values in the intervening ducts.

(f) The distortion is undoubtedly largely responsible for the reduction in volumes with angular velocity.

Explanations for these, and deductions from other tests are offered in the complete paper, but to secure brevity, are omitted here.

It was previously pointed out that in model 1 all teeth have sharp wedge notches. Laboratory tests on sections of teeth indicated that, for a given pressure, with the notches cut off the wedges, an average of about twice as much air would flow, as with the notches. In most large machines, the wedge notches are eliminated at the vent ducts. If, in model 1, this had been done, the pressure drop in the vents for a given volume through them would have been considerably less, and had the gap conditions remained the same, the drop in the gap would have been a greater percentage; consequently, the distortion would have been even greater.

For the intake vent ducts, in which we were unable to secure reliable data, there must be distortion, somewhat as in the outlets. The gap velocities are maximum near the division between an intake and an outlet belt. That represents a low-pressure region, and the largest pressure difference exists between the intake (connecting with the end bell) and that low-pressure region; consequently, those ducts have the greatest velocities of any intake vents. That is, the high velocity region in the intake vents is adjacent to a low-velocity region in the outlet vents, etc.

The conclusion reached is that the type of ventilation investigated with model 1 is undesirable, first because of the decrease in volumes with rotation, and second because of non-uniformity of discharge velocities, due to rotation. The non-uniformities, (distortion) occur for relatively long distances axially near the middle of the machine. Most of the heat generated in the tooth zones near the middle of a long machine must be carried away by moving air streams in that region; it cannot be conducted axially along the copper to the ends, as the length is too great; only a small fraction of it can be conducted circumferentially from tooth to tooth, because the length of the path is great, the cross-sectional area is small, and the thermal conduc-

11. We call departure from uniform circumferential distribution "distortion."

tivity of the steel is rather low[12]. Consequently, those teeth for which the air supply is small will heat considerably, and there will be high local temperatures.

A modification of model 1 type of ventilation consists in shunting some of the air which is admitted through the stator intakes through other paths of definite areas back of the teeth. If the same velocities are used in the teeth as with model 1 ventilation, and the same total volumes, then there is less air for the teeth, and the package thickness may be greater. With the same velocities in the teeth, nearly the same pressure of air must be used, and as the circumferential gap velocity is less, there probably will be a little less distortion. On the other hand, the thicker package of laminations means a greater drop in temperature axially; as that drop is proportional to the square of the thickness of the package, it may become an item of considerable magnitude. From an experimental viewpoint, the study of this type of ventilation would mean the development of an instrument for measuring air volumes (or velocities) in the various paths. No existing instrument is adapted to this. That would have required more time than was at our disposal. Many machines have been built with this type of ventilation, and it is claimed that they are satisfactory.

Model 2—Test Results

In this model the same rotor was used as for model 1. Numerous combinations were tried, only a few are even mentioned here. Thus, data were obtained for various combinations of air entering the gap through the main stator intakes, direct from the end bell, and through the rotor vents. Four different gap sections were obtained by filling those parts of the slots which were sunk below the stator inner periphery, and by turning down the rotor. Various combinations of numbers of intake and discharge vents were tried.

A realization of the importance of being able to estimate pressure drops suggested to us that full-size small models be built of a tooth vent section from the inner to the outer bore, and this model was so made that sharp, round, and blank wedge notches could be added. Pressure drops were measured for various volumes, with flow in either direction with one, two and no fingers. That in itself is quite a large and valuable research, the results of which could not be included even in the complete paper.

Fig. 23 shows the influence of pressure and speed upon the volume for conditions similar to those plotted in Fig. 16 for model 1; the air-gap depth was the same, and air was fed into the gap through the stator intakes and direct from the end bell. The pressures in Fig. 24 were, in general, considerably lower than in Fig. 16. However, the curves for 4.95 in. of water on Fig. 24, and for 5 in. on Fig. 16 are comparable. In model 1 there is a decrease of volume of 23.5 per cent from standstill to 3600 rev. per min., but in model 2, there is only 7 per cent decrease. The difference would have been even greater had there been the same restrictions in the vent ducts. With higher pressures of the order used in modern machines, the decrease in volume in model 2, due to rotation is nearly negligible. With this system of ventilation, circumferential distortion is absent, and therefore there is no increase in pressure drop due thereto, as was the case in model 1.

The volume distribution curves will be better understood by referring to Fig. 23. Consider first the discharge velocity belts. There are three: (a) the belt adjacent to the end bell: (b) the discharge belt between the two intake belts; and (c) the discharge belt beyond the second intake belt. If the losses of head in the gap and influences of rotation are neglected, the discharged velocity curves are cosines[13]. In the simplified case, illustrated in Fig. 23, the maximum velocity of the discharge in belt b is at the midpoint axially, and that point corresponds to zero gap velocity; equal volumes flow from the two adjacent intake belts toward the middle of the discharge belt b. The dis-

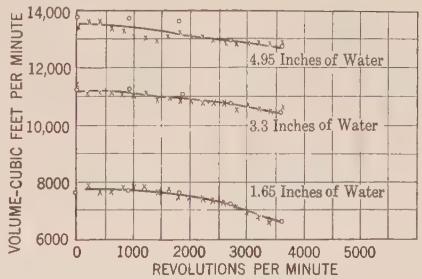

Fig. 24

Turbo Model No. 2. Volumes for various angular velocities and static pressure with stator + air gap open. Rotor external diameter = 26 in. Single air gap = 0.625 in. Stator slots sunk 0.625 in. Below stator inner periphery. Gap area = 0.553 sq. ft.

⊙ = Points taken Nov. 8, 1922.

x = " " Mar. 14, 1923

charge velocity is proportional to the derivative of the gap velocity. Consequently, if the discharge velocity curves are parts of cosines, the gap velocity curves are parts of sine curves, displaced from each other by 90 degrees; the maximum of one corresponds to the minimum of the other. For belt b it is assumed that there is a wall at the middle. The point at which the gap velocity becomes zero, (and the discharge a maximum), we have called the "balance point". In belt C the conditions are as for one-half of b; in c there is a definite mechanical stop at the far end.

In the first belt a, conditions are somewhat different. Assume that the pressures in the end bell and back of the first intake belt are equal. In general, the loss of head through the intake vents and up to the discharge belt is greater than at the gap entrance at the end

12. The thermal conductivity of low loss silicon steel is less than half the conductivity of ordinary steel; and the conductivity of ordinary steel is only about one-ninth of that of copper.

13. A physical explanation is given in the complete paper. The derivations of the equations are contained in the companion paper by Mr. Donald Bratt.

bell end, so that more total head is available for the discharge on the end bell side than at the intake side. It is almost evident, therefore, that the "balance point" in the first belt a, is usually not at the middle of the belt, but is nearer to the first intake belt, as indicated in Fig. 23. The discharge velocities are lower at the end bell side than at the intake side, as will readily be understood from previous explanations.

The intake velocities with the rotor stationary are at minimum value at the middle and maximum at the ends of the belts. This follows from the following: Gap velocities are zero at the middle, and maximum at the ends of the belts; the static pressures in the gap are, in consequence, at maximum at the middle, and minimum at the ends of the belt; the vent velocities are dependent upon the differences between the pressures back of the core and in the gap, and those differences are minimum at the middle and maximum at the ends of the intake belt. Neglecting losses of head in the gap, those velocity curves are hyperbolic, instead of trigonometric and are cosines for the vents, and sines for the gap, referred to the balance point.

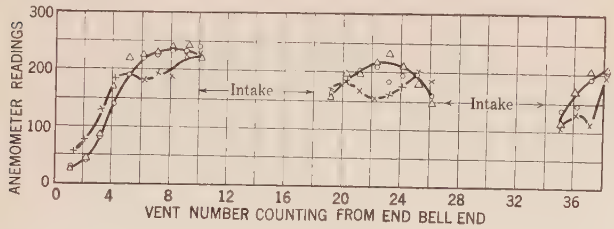

FIG. 31

Turbo Model No. 2. Volume distribution curves. All discharge vents open. Stator + air gap open. Edge at entrance package sharp. Taken with a pressure of 3.3 in. of water. Radial depth of air gap = 0.625. Slots sunk 0.625 in addition. Rotor external diameter = 26 in. Gap area = 0.553 sq. ft.

⊙ = Taken Oct. 24, 1922 rotor stationary 12,100 cu. ft. per min.
Taken Mar. 13, 1923 " " 12,000 " " " "
Taken Oct. 24, 1922 " at 3600 rev. per min. 11,400 " " " "

As in most complex phenomena, the actual curves can not be so simple. There is a loss of head in the gap, and the solution of equations with allowance for that loss complicates them considerably. However, those equations have been solved, but they are not yet ready for publication. The balance point in the first discharge belt is shifted; that, in turn, shifts the balance point of the first intake away from the middle; the location of other balance points are likewise affected, until, at the middle of the machine, the balance point is at the middle of the central belt. The influence of rotation also plays its part in distribution. However, the calculations based upon the comparatively simple assumptions, giving trigonometric and hyperbolic sine and cosine distributions is extremely useful and helpful, just as the use of the simple sine wave assumption in alternating-current calculations is of enormous help and usually gives results which are sufficiently accurate.

In Figs. 31 and 35, the distribution of volumes are shown for zero and 3600 rev. per min. for two different air-gap sections, with the stator intakes and the gap entrance from the end bell open; for Fig. 31 the internal diameter of the stator was the same throughout, whereas for Fig. 35 the wooden spacers, imitating steel packages of laminations, were cut back. It is of interest to note that the general shapes of the curves are substantially the same as in Fig. 23, especially at

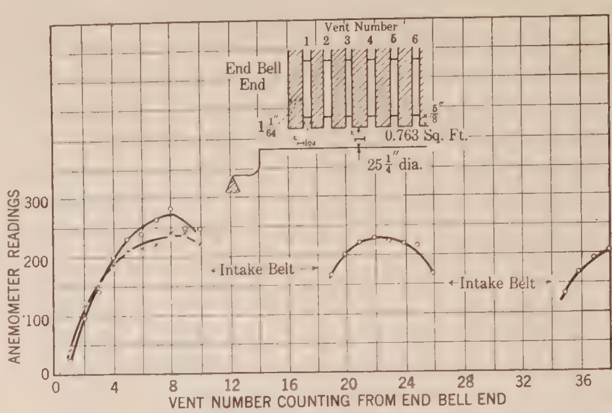

FIG. 34

Turbo Model No. 2. Volume distribution curves with sharp edges at first packages. 0.763 sq. ft. area in gap. Taken at a pressure of 3.3 in. of water in end bell.

⊙ = Turbo rev. per min. = 0
x = Turbo rev. per min. = 3600
Total volume = 14,400 cu. ft. per min. at standstill
" " = 13,500 cu. ft. per min. at 3600 rev. per min.
Stator + air gap.

zero speed. It should be noted that with this type of ventilation rotation tends, if anything, to secure more uniform distribution, rather than to produce distortion, as in model 1. Cutting back the first packages, (Fig. 35) assists toward making the distribution more

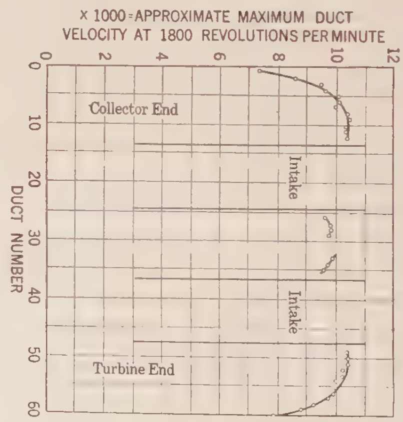

FIG. 36

Air velocities at minimum tooth sections in outlet vents in 25,000 kv-a. 1800 rev. per min., 60 cycles; turbo alternator.

uniform. Several ways for securing nearly uniform distribution of volumes were tried, some of which were successful.

The test results showing distribution of volumes (or velocities) in an actual machine are plotted in

Fig. 36[14]. Again, there is a striking agreement in shapes of curves with Fig. 23.

Some of the deductions for model 2 type of ventilation may be summarized. Additional deductions appear in the complete paper.

A. The total volumes are affected but little by the angular velocity; the decrease in any case is very much smaller than for model 1 type of ventilation. For air pressures of the order that are now used in large machines, without air fed through the rotor vents, the decrease is negligible.

B. With large air gaps, the decrease in volume due to rotation is practically negligible.

C. The axial distribution of volumes in the discharge belts approach cosine curves, with minimum values at the ends of the belts. The corresponding velocities in the air-gap approach sine curves, whose zero values correspond to the maximum on the cosine curves. In the intakes the curves are approximately hyperbolic; for radial flow the maximum values are at the ends of the belts, and for the gap flow, the zero values correspond to the minimum values on the radial flow curves.

D. The radial velocities are proportional to the derivatives of the gap velocities.

E. The discharge vent velocities decrease as the gap velocities increase; the intake vent velocities increase with the gap velocities.

F. The position of the maximum point on the discharge velocity curve can be shifted by various mechanical means, such as a ring in the air gap, or change of entrance conditions to the belt of vents.

G. The distribution of discharge volumes (axially) is modified by the influence of rotation, the tendency being to make the volume more uniform. The smaller the gap, the greater is that influence.

H. It is desirable to have somewhat lower volumes in the vents adjacent to the end bells than in other vents, in order that more uniform temperatures be secured longitudinally.

I. The air entering the air gap direct from the end bell is arithmetically additive to that volume entering the gap from the first intake belt, and flowing toward the same discharge belt. This is quite different than for model 1.

14. The method used for taking these curves is given in the complete paper.

CRYSTALS IN PORCELAIN— A CORRECTION

BY F. H. RIDDLE

The writer recently presented a series of articles in the JOURNAL* in which the composition of porcelain was described, together with the pyrochemical reactions which take place during the firing. It was shown that the firing brought about a combination of certain parts of the silica and alumina first in the amorphous and crypto-crystalline form and later, due to the effect of time and temperature, needle like crystals were formed. These crystals have been generally understood to be of the composition $Al_2 O_3 Si O_2$ and hence have been called sillimanite. Sillimanite is a definite natural mineral of the composition $Al_2 O_3 . Si O_2$ and petrographers have repeatedly pronounced the crystals found in porcelain to have the same optical properties as the natural mineral and hence have called it sillimanite.

Continued work on the part of the Geophysical Laboratory of the Carnegie Institute has recently brought out the fact that the crystals found in porcelain really have the composition $3 Al_2 O_3 . 2 Si O_2$ and not $Al_2 O_3 . Si O_2$ hence they are not sillimanite and are yet unnamed. This discovery was brought out in a paper presented before the Geological Society of America in December, 1923, by N. L. Bowen and J. W. Greig of the Geophysical Laboratory.

They show that both the nautral mineral sillimanite $Al_2 O_3 . Si O_2$ and the artificial $3 Al_2 O_3 . 2 Si O_2$ crystals have nearly square prism angles with one cleavage diagonal to the prism. The plane of the optic axes is parallel to this cleavage and the elongation is positive. The difference can be seen only when precise quantitative measurements of optical and crystallographic properties are made and even then they are very closely related, the differences being shown as follows in two of many samples tested.

		$3Al_2O_3 . 2SiO$	Natural Sillimanite
Prism Angle	(110 $\wedge$ 110)	89° 13′	88° 15′
Refractive indices	γ (gamma)	1.654	1.677
	α (alpha)	1.642	1.657
Axial angle	2 γ	+ 45° to 50°	+ 25°

The differences are made still more difficult to determine when small amounts of iron and titanium are present and it is very difficult to find clays in which these two elements are not present.

The formation of the crystals in ceramic bodies in the 3-to-2 form instead of the 1-to-1 means that less silica is present in the crsytal and hence more in the glassy matrix. This new development will in no way change the general descriptions given in the writer's articles excepting as mentioned.

When natural sillimanite or andalusite are incorporated into a body batch, the crystals will change from the 1:1 ratio to $3 Al_2 O_3 . 2 Si O$ setting free excess silica at the proper temperatures, and the crystals will form in their exact position, part of the excess silica being pushed out to go into solution in the glassy matrix. It is easy to see how this formation would cause much less disturbance in the body than does the formation of the crystals from clay where the clay has been dissolved and the crystals have formed by crystallization from the flux.

*April, May and June, 1923, A. I. E. E. JOURNAL.

Overdamped Condenser Oscillations

BY CHARLES P. STEINMETZ*
Fellow, A. I. E. E.
Chief Consulting Engineer, General Electric Co.

Review of the Subject.—*In the classical equations of the discharge of a condenser of capacity C into an external circuit of resistance r and inductance L, it is found that the discharge is oscillatory if* $r < \sqrt{\frac{4\,L}{C}}$*, and is impulsive if* $r > \sqrt{\frac{4\,L}{C}}$.

As the perfect condenser can never be realized in practise, it is the purpose of this paper to show the effect of the condenser leakage on the discharge wave.

The imperfect condenser is represented by the perfect condenser C shunted by the conductance g. This condenser discharges into the circuit L and r as above. The mathematical discussion shows that no matter what the relation between r and $\sqrt{\frac{4\,L}{C}}$*, there may always exist some value of g for which the discharge is oscillatory. This is the case when*

$$(r/L - g/C) < \sqrt{\frac{4}{L\,C}}$$

$$i.\,e.,\ r < \sqrt{\frac{4\,L}{C}} + \frac{g\,L}{C}.$$

It is to be borne in mind that the above holds true only when r, L, C, and g are constant. If the resistance is that of a third class conductor, the discharge will always be oscillatory.

An apparent paradox is found in the statement that the current may be more than 90 deg. out of phase with the voltage. A study of the derived equations, remembering that the current under consideration is only one of the two components forming the total discharge current $\left(C\,\frac{d\,e}{d\,t}\right)$ *of the condenser (the leakage current* $g\,e$ *being the other), will show that this is true. A study of the oscillograms will further confirm the theory.*

I. General and Experimental

The classical equations of the condenser discharge through an inductive circuit show that the discharge is oscillatory, if the resistance of the discharge circuit is less than a certain critical value $2\sqrt{L/C}$; and in this case the damping of the wave is geometric, that is, the quotient of two successive half waves is constant. The discharge is impulsive, if the resistance of the discharge circuit is greater than the critical value.

This, however, applies only if the circuit factors: resistance, inductance and capacity, are actually constant. It does not apply if the resistance is that of a third class conductor, that is, if the potential drop across the resistance decreases with increase of current. In this case the discharge is always oscillatory, but the damping is either arithmetic, that is the difference of two successive half waves is constant, or it is a combination of arithmetic damping and geometric cumulation.[1]

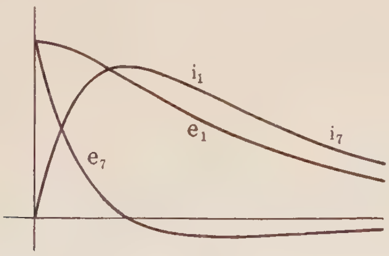

Fig. 1

Even with constant values of resistance, inductance, and capacity, the classical condenser discharge equations hold only for the *ideal condenser*, that is, a condenser in which no energy losses occur. *If energy losses occur in the condenser*—as is usually the case—*the discharge remains oscillatory even for values of the discharge resistance greater than the critical value* $2\sqrt{L/C}$, and the discharge oscillates the more, the higher the energy losses in the condenser. No matter how high the resistance of the discharge circuit, there always exists a value of energy loss in the condenser (which depends on the value of the discharge resistance) at which no impulsive discharge is possible, but the discharge is always oscillatory. This occurs when the

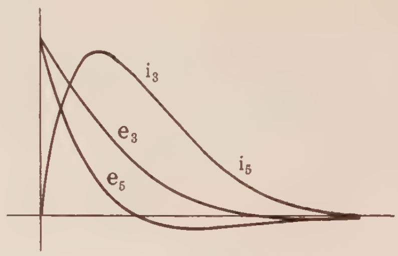

Fig. 2

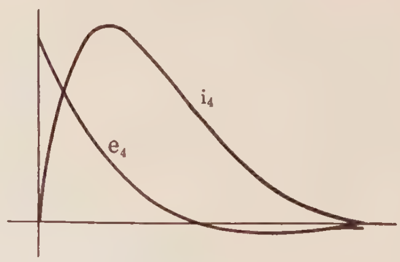

Fig. 3

*Deceased.

1. See A. I. E. E.

Presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

damping of the wave due to energy losses in the condenser, equals that due to the discharge resistance. The damping is then geometric.

The frequency of the oscillation, and the limit up to which the discharge is oscillatory, depends on the *difference* between the power dissipation in the discharge resistance, and that in the condenser losses, while the attenuation or damping of the discharge wave depends on the *sum* of the losses. As a result of the combined losses, such discharge waves may have rates of attenuation far greater than possible in the classical equations of the ideal condenser. They may therefore be called *Overdamped Oscillations.*

Fig. 4

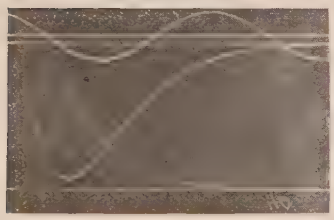

Fig. 5

Fig. 6

In such overdamped discharge oscillations of the imperfect condenser, only a fraction of the first half wave may be of appreciable magnitude. That is, in the current wave, the maximum (which with the alternating wave occurs at 90 deg., and with a wave of low damping near 90 deg.) may occur at 20 deg. to 30 deg. and still earlier; the wave from then is very much steeper than the wave tail, similar to the case in the non-oscillatory impulse; the wave shape however, differs from the latter, and the current and voltage wave pass through zero at a definite point, while in the non-oscillatory impulse they never reach zero, but gradually fade out.

As illustrations are shown in Figs. 1 to 3 the calculated current and voltage waves and in Figs. 4 to 7 the observed oscillograms of a series of such overdamped condenser discharge waves, for a condenser of $C = 5\ \mu$f. capacity discharging through an inductance of 5

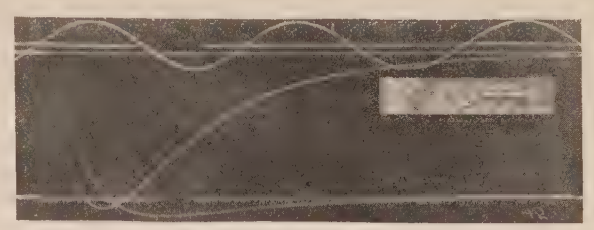

Fig. 7

henrys. This gives the critical resistance $r_0 = 2\sqrt{L/C} = 2000$ ohms.

As (1) is shown the discharge, given by the classical equations for zero condenser loss and a discharge resistance of $r = 2400$ ohms, that is, an impulsive or unidirectional discharge.

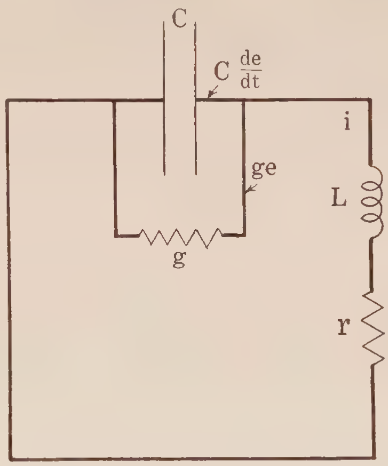

Fig. 8

In (2) the discharge resistance has been reduced to 2100 ohms (which with a loss free condenser would still give an impulsive discharge) but such a power dissipation in the condenser has been assumed, as to give the same damping constant as (1). The discharge then has become oscillatory.

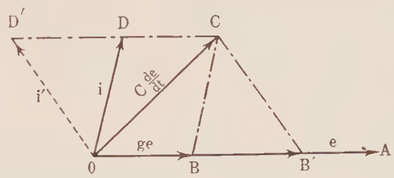

Fig. 9

(3) to (7) give the discharges for successively lower discharge resistances. $r = 1800$, 1200, 600, 300 and 0 ohms, but with successively increased power dissipation in the condenser, so as to give the same total resultant dissipation constant. As seen, in (7), for zero

discharge resistance, the discharge has again become impulsive, due to the strong damping by the condenser losses, although the shape of the voltage impulse is very different from that in (1). The frequency of the discharge increases with increasing condenser losses, up to (4), the case at which the condenser losses equal the losses in the external circuit and the condenser losses neutralize the effect, on the frequency, of the discharge resistance, and the frequency is the same as that of an undamped wave.

(1) to (7) thus give forms of waves, of the same condenser discharging through the same inductance with the same damping, that is, the same attenuation constant, but the losses, that is, the power dissipation which causes the damping, shifting from all in the external circuit and none in the condenser, in (1) to all in the condenser and none in the external circuit, in (7). As seen, the current waves in (7), (6) and (5) are the same as in (1), (2) and (3); but the voltage waves are materially different.

As a further illustration, the current and voltage discharge waves of the same condenser are calculated, $C = 5\ \mu$f. over the same inductance $L = 5$ henrys, and a constant discharge resistance $r = 2400$ ohms, and with amounts of power dissipation in the condenser, varying from zero in (1), up to a value in (5), which doubles the dissipation constant of the discharge.

II. Mathematical

Let:

C = Capacity of the condenser

L = Inductance of the discharge circuit

r = Resistance of the discharge circuit (including the effective resistance representing the energy losses in the inductance).

If energy losses occur in the condenser, an energy component occurs in the condenser current, which can be represented by an effective shunted resistance or shunted conductance. Thus let:

g = Effective shunted conductance representing energy losses in the condenser.

We thus have, in the general case:

C = Coefficient of energy storage by the voltage, in the capacity of the condenser

L = Coefficient of energy storage by the current, in the inductance of the external circuit

g = Coefficient of power dissipation by the voltage, in the effective shunted conductance of the condenser

r = Coefficient of power dissipation by the current, in the (effective) resistance of the external circuit.

Let:

e = Voltage at condenser terminals, with $e = e_0$ as initial value at time $t = 0$

i = Current in the external circuit, with $i = 0$ as initial value.

It is then:

In the external circuit:

$$e = L \frac{d\,i}{d\,t} + r\,i \tag{1}$$

In the condenser:

$$-\,i = C \frac{d\,e}{d\,t} + g\,e \tag{2}$$

Substituting (1) and its differential into (2) gives the differential equation of current:

$$\frac{d^2\,i}{d\,t^2} + 2\,u \frac{d\,i}{d\,t} + \frac{1 + r\,g}{L\,C}\,i = 0 \tag{3}$$

where:

$$u = 1/2\,(r/L + g/C) \tag{4}$$

is the attenuation constant, and

$$m = 1/2\,(r/L - g/C) \tag{5}$$

is the distortion constant.[2]

Equation (3) is integrated in the usual manner by terms of the form:

$$i = A\,\epsilon^{-ct}$$

which, in the case that c becomes imaginary, combine to a term:

$$i = B\,\epsilon^{-ct} \sin q\,t$$

and by the substitution of the terminal conditions, gives:

A. Impulsive Discharge

$$m^2 > \frac{1}{L\,C} \tag{6}$$

$$i = \frac{e_0}{2\,s\,L}\left(\epsilon^{-c_1 t} - \epsilon^{-c_2 t}\right) \tag{7}$$

$$e = e_0 \left(\frac{m + s}{2\,s}\,\epsilon^{-c_1 t} - \frac{m - s}{2\,s}\,\epsilon^{-c_2 t} \right) \tag{8}$$

where:

$$\left.\begin{aligned} c_1 &= u - s \\ c_2 &= u + s \end{aligned}\right\} \tag{9}$$

$$s = \sqrt{m^2 = \frac{1}{L\,C}} \tag{10}$$

The current is a maximum at the time:

$$t = \frac{\log c_2 - \log c_1}{2\,s \log \epsilon} \tag{11}$$

B. Critical Discharge

$$m^2 = \frac{1}{L\,C} \tag{12}$$

$$i = e_0/L\,t\,\epsilon^{-ut} \tag{13}$$

$$e = e_0\,\epsilon^{-ut}\,(1 + m\,t) \tag{14}$$

2. See A. I. E. E., "The General Equation of the Electric Circuit," 1907. Also: "Theory and Calculation of Transient Phenomena, Section IV," page 462, 509.

The current is a maximum at the time:

$$t = \frac{1}{u} \tag{15}$$

C. Oscillatory Discharge

$$m^2 < \frac{1}{L\,C} \tag{16}$$

$$i = \frac{e_0}{q\,L}\,\epsilon^{-ut}\sin q\,t \tag{17}$$

$$e = e_0\,\epsilon^{-ut}\,(\cos q\,t + m/q \sin q\,t) \tag{18}$$

where:

$$q = \sqrt{\frac{1}{L\,C} - m^2} \tag{19}$$

The current is a maximum at the time:

$$\tan q\,t = q/u \tag{20}$$

As seen, with increasing energy loss in the condenser, m decreases to zero and then becomes negative, and the phase relation between voltage and current thus changes from less than quadrature to quadrature to more than quadrature.

Although at first glance this statement may seem impossible, and may be impossible for steady conditions, we believe that this, like many other seeming paradoxes in the study of transients, is perfectly true.

Referring to the diagrams, in Fig. 8 the capacity c, shunted by the conductance g, represents the imperfect condenser.

$c\,\frac{d\,e}{d\,t}$ = current supplied by condenser

$g\,e$ = current through g (through imperfect condenser)

i = current through L and r (external circuit)

e = condenser voltage

(1) The current $g\,e$, being through the pure resistance g, must be in phase with the voltage e.

(2) The vector sum of the currents through the external circuit (L and r) and through g must be equal to the current supplied by the condenser.

In Fig. 9

$A\,O$ represents the condenser voltage e

$B\,O$ represents the current $g\,e$ in phase with e

$C\,O$ represents the condenser current $C\,\frac{d\,e}{d\,t}$, out of phase with e by the angle $C\,O\,A$

$D\,O$ represents the external current i, out of phase with e by the angle $D\,O\,A$

Now, change the circuit constants (g, L, and r) so that $C\,\frac{d\,e}{d\,t}$ has the same relation to e as before, but $g\,e$ has taken the position $O\,B'$. Then, as the vectorial sum of $i/g\,e$ must be equal to $C\,\frac{d\,e}{d\,t}$, then i must take the position $O\,D'$ which is displaced from c by the angle $D'\,O\,A$ obviously greater than 90 deg.

A study of oscillograms for cases 5, 6 and 7 of the first instance given in the paper will corroborate the above analysis.

D. Notes

The energy dissipation in the system is given by the same equations in all three cases, as:

$$r\,(I^2) + g\,(E^2) = r\int_0^\infty i^2\,d\,t + g\int_0^\infty e^2\,d\,t$$

$$= \frac{r\,e_0^2\,C}{4\,L\,u\,(l + r\,g)} + \frac{g\,e_0^2\,(l + u\,r\,C)}{4\,u\,(l + r\,g)} \tag{21}$$

The current slope is a maximum for:

$$\left|\frac{d\,i}{d\,t}\right|_{t=0} = e_0/L$$

The voltage slope is a maximum for:

$$\frac{d^2\,e}{d\,t^2} = 0$$

at:

$$\tan q\,t = \frac{q^2 - u^2}{2\,q\,u}$$

$$\frac{d\,e}{d\,t} = -\,e_0\,\epsilon^{-ut}\,(u\cos q\,t + q\sin q\,t)$$

In the classical equations of the condenser discharge, the term $\frac{r}{2\,L}$ takes the place of both of the terms, u and m, of the general equations.

III. Instances

As an instance, let: e_0 = 10,000 volts.

C = 5 μf. = 5×10^{-6} = capacity of condenser

L = 5 henrys = inductance of discharge circuit, thus:

$z_0 = \sqrt{L/C}$ = 1000 ohms = surge impedance, and

$r = 2\,z_0$ = 2000 ohms = critical resistance, at which the discharge of the ideal condenser changes from oscillatory to impulsive.

$$\frac{1}{L\,C} = 200 = \text{frequency constant.}$$

Choosing then the discharge resistance r, and the shunted conductance of energy loss in the condenser g, so as to give a constant attenuation, that is, at constant total attenuation u, the energy losses are divided between the external circuit and the condenser, in different proportions.

$$u = 1/2\,(r/L + g/C) = 240$$

Seven cases are given in Figs. 1 to 3 and oscillograms Figs. 4 to 7, for the constants:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
No.	1	..	2	3	2	..	1
Figs.	..	..	4	5	6	..	7
r =	2400	2100	1800	1200	600	300	0 ohms
g =	0	0.3	0.6	1.2	1.8	2.1	2.4×10^{-3} mhos
thus m =	240	180	120	0	−120	−180	−240
$q = \sqrt{\frac{1}{LC} - m^2}$ =	..	87.2	160	200	160	87.2	..
$s = \sqrt{m^2 - \frac{1}{LC}}$ =	132.6	..	..	..	..	..	132.6

Current	Terminal Voltage at Condenser
(1) $i = 7.55\,(\epsilon^{-107.4t} - \epsilon^{-372.6t})$	$e = 10000\,(1.41\,\epsilon^{-107.4t} - .41\,\epsilon^{-372.6t})$
(2) $i = 23\,\epsilon^{-240t} \sin 87.2t$	$e = 10000\,\epsilon^{-240t}(\cos 87.2t + 2.07 \sin 87.2t)$
(3) $i = 12.5\,\epsilon^{-240t} \sin 160t$	$e = 10000\,\epsilon^{-240t}(\cos 160t + .75 \sin 160t)$
(4) $i = 10\,\epsilon^{-240t} \sin 200t$	$e = 10000\,\epsilon^{-240t} \cos 200t$
(5) $i = 12.5\,\epsilon^{-240t} \sin 160t$	$e = 10000\,\epsilon^{-240t}(\cos 160t - .75 \sin 160t)$
(6) $i = 23\,\epsilon^{-240t} \sin 87.2t$	$e = 10000\,\epsilon^{-240t}(\cos 87.2t - 2.07 \sin 87.2t)$
(7) $i = 7.55\,(\epsilon^{-107.4t} - \epsilon^{-372.6t})$	$e = 10000\,(-.41\,\epsilon^{-107.4t} + 1.41\,\epsilon^{-372.6t})$

In the oscillograms, as nearly as possible the same constants were chosen, and as seen, the oscillograms are identical in wave shape with the calculations, (except for a slight inductive effect at the beginning of the voltage wave). For convenience, the current is shown in reverse direction, and as time measure, a 60-cycle wave is given.

As a second instance, consider:

The same e_0, C, L, z_0, etc. but a constant value of the discharge resistance:

$$r = 2400 \text{ ohms}$$

and various values of shunted conductance g, from zero to a value equal in energy dissipation to r. That is:

	No.	(1)	(2)	(3)	(4)	(5)
	g =	0	.3	.6	1.2	2.4×10^{-3} mhos
thus	u =	240	270	300	360	480
	m =	240	210	180	120	0
	q =	..	..	87.2	160	200
	s =	132.6	64.2	..	..	..

Current	Voltage at Condenser Terminals
(1) $i = 7.55\,(\epsilon^{-107.4t} - \epsilon^{-372.6t})$	$e = 10000\,(1.41\,\epsilon^{-107.4t} \epsilon .41\,\epsilon^{-372.6t})$
(2) $i = 15.6\,(\epsilon^{-205.8t} - \epsilon^{-334.2t})$	$e = 10000\,(2.14\,\epsilon^{-205.8t} - 1.14\,\epsilon^{-334.2t})$
(3) $i = 23\,\epsilon^{-300t} \sin 87.2t$	$e = 10000\,\epsilon^{-300t}(\cos 87.2t + 2.07 \sin 87.2t)$
(4) $i = 12.5\,\epsilon^{-360t} \sin 160t$	$e = 10000\,\epsilon^{-360t}(\cos 160t + .75 \sin 160t)$
(5) $i - 10\,\epsilon^{-480t} \sin 200$	$e = 10000\,\epsilon^{-480t} \cos 200t$

Experience with Bearings and Vibration Conditions of Large Hydroelectric Units

BY JOHN HARISBERGER

Member, A. I. E. E.

Puget Sound Power & Light Co.

IN 1905 there was installed at Snoqualmie Falls, a 9000-h. p. single-runner, single-discharge Francis turbine. The end thrust of this runner gave considerable trouble, since the balancing of the run in a turbine of this type had not been perfected at that time. This experience determined that any future horizontal hydraulic turbine should be of the single-runner, double-discharge type unless a satisfactory solution was found for balancing the runner in a single-discharge turbine.

In 1910 a 12,000-h. p. single-runner, double-discharge turbine was installed under a 280-ft. head. When this turbine was put in operation it was found that it would begin to vibrate badly at about ¾ load and would not stop vibrating until the load was reduced to ¼ gate opening. This vibration was similar to that caused by running a high-speed turbine with a badly unbalanced runner. Numerous experiments were tried to stop the vibration, but without satisfactory results. Finally water was piped from the penstock to the turbine case to be used in the pocket between the runner and other parts, such as the side covers and inner and outer seal rings, resulting in an increased pressure and a steadying effect on the runner. It was then possible to carry full load without vibration. With this arrangement we were able to adjust the clearance between runner and seal rings very closely, so that very little wear of the seal rings and periphery of the runner resulted.

In 1911 two 20,000-h. p., single-runner, double-discharge turbines were installed in our White River station, under a head of 440 ft. The experience with these units was similar to that at Snoqualmie Falls, and the same remedy proved effective. A third unit was installed in this station in 1917, and an attempt was made in its design to overcome the vibration, such as occurred in the previous units, without the introduction of pressure water to the side covers. Since we were satisfied that the main cause of vibration was the long distance between bearings made necessary by the two draft tubes, (this being over 20 ft.), the change in design consisted principally of a larger and stiffer shaft. Nevertheless it was found necessary to apply water pressure between seal rings and side covers and runner as on the previous units.

No. 3 turbine did not come up to the capacity expected, so another runner of somewhat different design was installed, which exceeded our expectations as to capacity. With this new runner, we found that a decided hum, or vibration, developed, beginning at about $^3/_{10}$ gate opening and continuing to a little beyond $^5/_{10}$ gate opening with a maximum intensity at about $^4/_{10}$ gate opening. At its maximum, this vibration in the runner is quite annoying and is sufficient to start vibrations in any loose metal parts, such as valve

Presented at the Pacific Coast Convention of the A. I. E. E., Del Monte, Cal., October 2-5, 1923.

wheels, covers, or balancing rings, so care must be taken to fasten these parts to keep them from wearing rapidly. We have not obtained any expression from the manufacturer of the turbine as to the cause of this hum, but we came to the following conclusion. The tone of this hum is somewhat above the 60-cycle hum. A study of the frequency of the vibration was made by comparing the generator and the turbine as follows:

Let S = speed of turbo generator in revolutions per minute.

C = the number of vibrations per minute of the generator tone.

E = the number of vibrations per minute of the turbine tone.

N = the number of poles on generator field.

V_1 = the number of vibrations per minute of generator.

V_2 = the number of vibrations per minute of the turbine.

X = the number of vibrations per revolution of turbine.

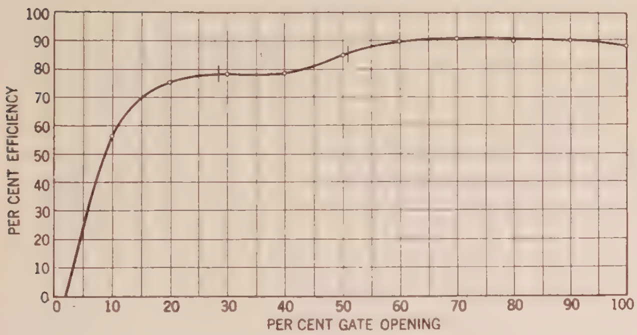

FIG. 1—GATE OPENING EFFICIENCY CURVE
Turbine No. 3, White River Generating Station

Then

$$V_1 = N\,S$$

$$V_2 = \frac{V_1 E}{C} = \frac{N S E}{C}$$

$$X = \frac{N\,E}{C} = 25$$

In this particular case

N = 20
S = 360
C = 60 × 256
E = 60 × 320

As there are 25 buckets on the turbine runner and a vibration occurs only over a limited range of gate opening, vibrations have been considered as due to the relative entrance angle of the runner-blades to the flow angle of the entering water. This flow-angle is varied at different gate openings by the angle of guide vanes and the velocity of the water as it enters the runner, the speed of the runner remaining constant.

Fig. 1, the efficiency curve of this runner, shows a decided sag in the curve between points where this vibration takes place, owing no doubt, to the deflection of the entering water caused by the blades.

The original bearings furnished with two of our large generators were babbitted with a lead base babbitt which was unsuitable for heavy service. Before satisfactory operation could be obtained these bearings had to be rebabbitted with babbitt suitable for heavy pressure. These bearings were 15 by 45 in. with five brass oil rings, and carried a rotor complete, with shaft, weighing 120,300 lb., and operating at 360 rev. per min. The bearings as originally constructed were equipped with cooling coils consisting of several longitudinal tubes placed at the bottom of the oil reservoir, and were not effective for cooling the oil as there was not sufficient circulation to carry the hot oil to the bottom of the well. During the hot weather considerable difficulty was experienced with high temperature. It was necessary to install a temporary system for feeding the oil into the top of the bearings. Different kinds of oils were tried out with the hope of reducing the bearing temperature, and also copper cooling coils were installed in oil wells immediately below the bearings. The cooling coils so reduced the oil temperature that it was not necessary to continue feeding oil into the top of the bearings. The third unit installed in this station, was somewhat larger than the previous two, having bearings 17 by 34 in., with 4 oil rings, and carrying a rotor weight of 136,000 lb., and operating at 360 rev. per min. The cooling coils of these bearings are imbedded in the babbitt. These bearings were so successful that bearings of this type have replaced the original ones in turbines No. 1 and 2. The only difficulty experienced since the changes were made in the bearings, as mentioned above, was that the shaft, on being started after having been shut down for a number of hours, cohered to the babbitt and wiped a spot in it on the lower half of the bearing. In some instances this effect was indicated by smoke rising from the bearings just as the shaft started to turn over but subsequently the bearings continued to operate without further trouble. When after trouble of this kind the bearing was dismantled, a small spot was found wiped near the bottom of the bearing, but the cohesion was not sufficient to pull the babbitt all the way around. On other occasions wiping was more serious and as a result it was necessary to shut down the turbine and scrape the bearing. As a precautionary measure in starting the turbine, a small amount of clean oil is poured on the bearing to supply lubrication during the first revolution. To overcome completely this tendency to cohere, we are installing a high-pressure oiling system to force oil under the shaft before starting up.

Circuit Breaker Tests at Bessemer, Ala.

On 300-Ampere, 110,000-Volt Breakers

BY J. D. HILLIARD
General Electric Co., Schenectady, N. Y.

THE tests herein described were made possible through the cooperative efforts of the Alabama Power Company's officials, engineers and operators. The writer desires to express his appreciation to them, and to call attention again to the value that

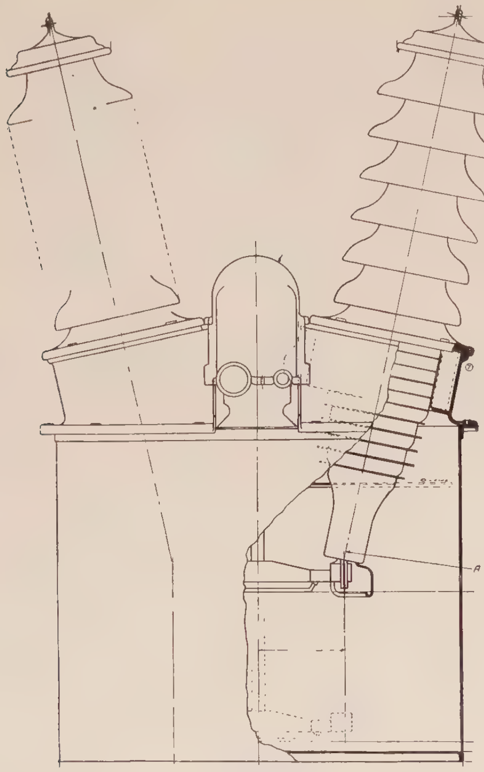

Fig. 1

properly conducted field tests have in the manufacture of apparatus.

With the increase in capacity of the generating equipment of the Alabama Power Company, the power available under short-circuit conditions became so great at various substations that it exceeded the rated interrupting capacity of the oil circuit breakers on the 110,000-volt circuits. The Alabama Company had installed on its system a large number of type *F K O-21A* and *F K O-22 A*, 300-ampere, 110,000-volt oil circuit breakers and the General Electric Company was asked if the rating of these breakers could in any way be increased and the breakers made more satisfactory to handle the increased load.

In this paper the results of the tests on the rebuilt 110,000-volt breaker, together with the tests on plain break and explosion chamber 44,000-volt breakers, are described. The 110,000-volt breakers as originally supplied to the Alabama Company were of the plain break contact-finger type shown in Fig. 1.

The arrangement of the system, the general method of test, and a discussion of the effect on the system are described in another paper presented at this session.

110,000-Volt Tests

These breakers were rebuilt to equip them with explosion chambers. This necessitated increasing the height of the oil tank. New insulating linings were also added. The plain break contacts originally used are shown on Fig. 2 and the explosion chamber contacts with which they were replaced and on which the tests were made are shown in Fig. 3.

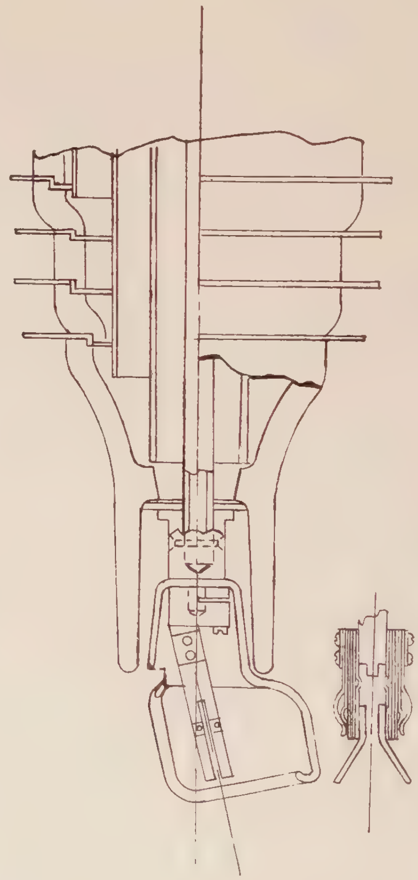

Fig. 2

The increase in height of tank, which was to provide for the height occupied by the explosion chamber, was done by the Alabama Power Company by means of an acetylene weld. The remainder of the materials necessary to make the changes were supplied by the General

Presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924.

Electric Company, all the work of installation being done by the Alabama Power Company. After the specified changes had been made on a single pole unit, tests were made upon it in order to observe its action under various short-circuit loads, and to determine that it had a safe interrupting capacity of 450,000 kv-a. under their circuit conditions. The system arrangement and line reactances upon which the tests were made are shown in Fig. 4. These tests were made during January, 1922.

During the tests, the test breaker was tapped from one line of a Y-connected grounded transmission system, namely on phase 3 of line *B* from Magella to Bessemer.

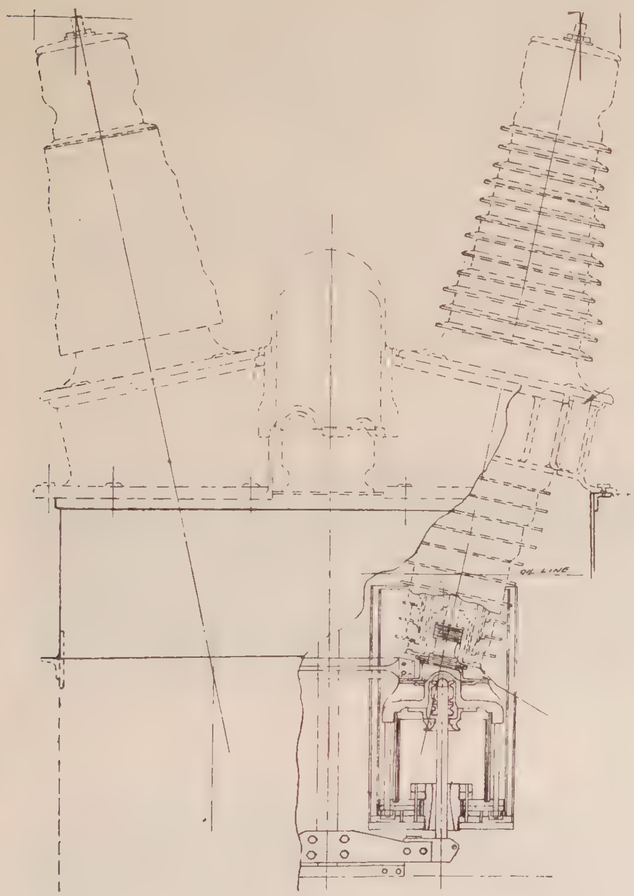

Fig. 3

This line *B* was connected to No. 2 bus at Bessemer, but was open at Magella. One side of the breaker was connected to ground through a shunt. This shunt being at ground potential, it was possible to run leads from it to the current vibrator of the oscillograph. A potential transformer was not available for the tests, so the potential vibrator on the oscillograph was connected indirectly to the delta-connected low-tension windings of the 110,000-volt power transformers. This explains why the characteristic arcing record is not shown on the oscillogram.

The short circuit was thrown on by service breaker No. 806 and was opened by the breaker under test. In no case was the breaker under test used to close as well as to open the circuit and in this respect conformed to the Baltimore tests which preceded it. It should also be noted that all tests were made single-phase from line to ground and that the neutral of the power transformers were therefore grounded.

To avoid any possibility of injury to the oscillograph operator, the oscillographic apparatus was located upon an insulating stand.

The attempt was made in some of the tests to obtain pressure records by means of an indentation recorder—steel ball on a copper plate—but it was so slow in operation that the attempt was given up. The test records show the currents, voltages and speeds.

In considering these tests, it should be realized that an old style breaker structure was under investigation, one which had been built without any especial preventive means to guard against oil throw, and which in comparison with our present day standards was wide open for the escape of oil.

During the test, circuit connections were changed and generators added or taken off as necessary to give the desired interrupted current. The following table is a summary of the results of the tests.

R. m. s. Amps. in Arc	Equivalent kv-a. 3-Phase	Arc Length Inches	Contacts Speed Ft./Sec.	Oil Throw	Signs of Distress	Approx. Generators Connected
220	38,100	4.6	4.87	None	None	70,000 kv-a.
445	84,800	3.95	4.65	"	"	86,000 kv-a.
1215	231,000	8.35	5.56	1 pt.	2	70,000 kv-a.
1225	233,000	8.74	..	None	"	114,000 kv-a.
1560	297,000	7 87	5.48	1 pt.	"	70,000 kv-a.
1710	326,000	7.65	6.64	1 pt.	"	86,000 kv-a.
1720	327,500	8.35	5.75	1 pt.	"	144,000 kv-a.
1935	368,300	7.46	5.75	2 qts.	"	114,000 kv-a.
2010	382,500	8.86	6.25	1 qt.	"	114,000 kv-a.
2180	415,000	7.35	6.65	1 qt.	"	114,000 kv-a.
2220	422,500	7.66	6.30	1 pt.	"	144,000 kv-a.
2220	422,500	8.23	6.40	1 pt.	"	144,000 kv-a.
2225	424,000	10.00	6.55	1 pt.	"	144,000 kv-a.

The arc length was determined from the speed recorder and the design data of the breaker. The lack of a potential transformer across the breaker contacts detracts somewhat from the value of the films, but, nevertheless, there are some that are of interest in showing the nature of the results. Fig. 5 shows an interruption with a current value of 2740 amperes as the r. m. s. of the first peak of short circuit and 2220 r. m. s. amperes in the first half cycle of arc. *A* is the voltage across line 1 and 2, *B* is the current in line 3, and *C* is a speed record.

It will be noted that the decrement current was small and this is characteristic of all of the tests.

Fig. 6 shows the current and speed records on an interruption having a maximum r. m. s. at first half wave of short circuit of 2370 amperes, and 1710 amperes in the first half wave of arc.

Fig. 7 shows the current and speed on an interruption of 1610 amperes r. m. s. first half cycle at short circuit and 1235 r. m. s. first half cycle of arc. The

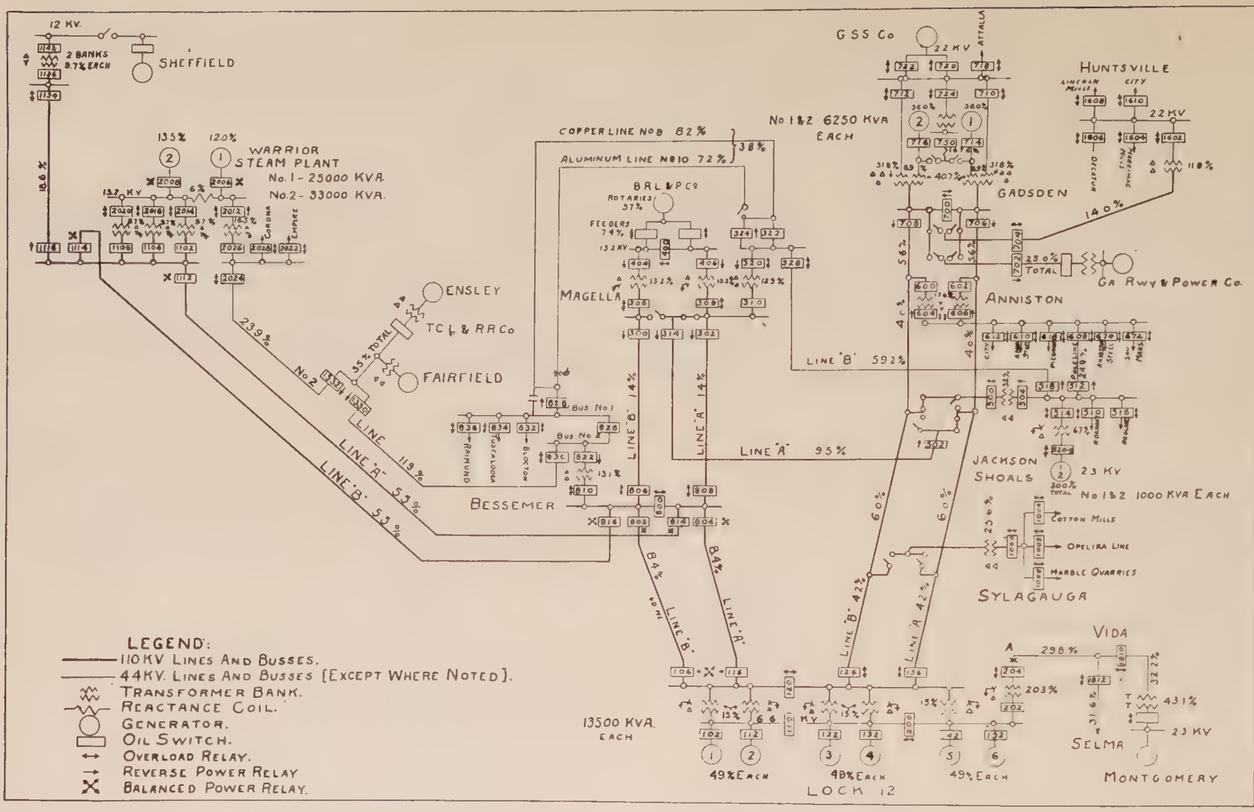

Fig. 4

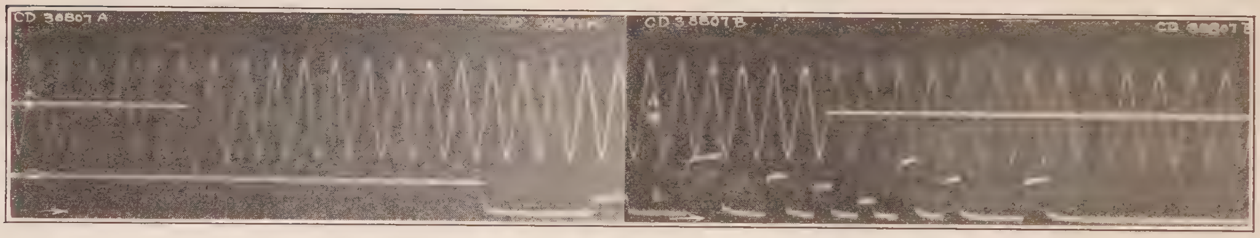

Fig. 5

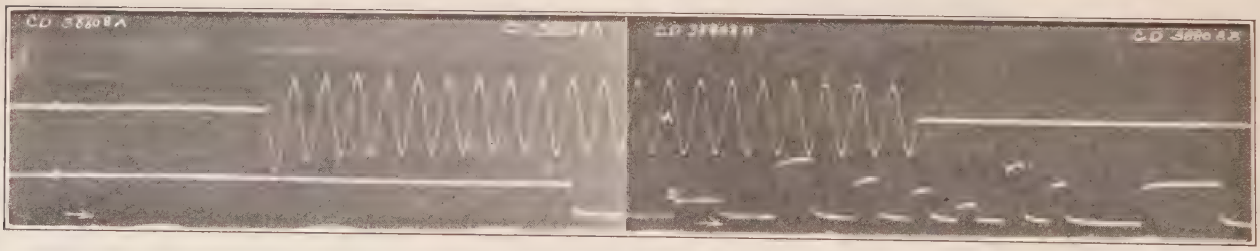

Fig. 6

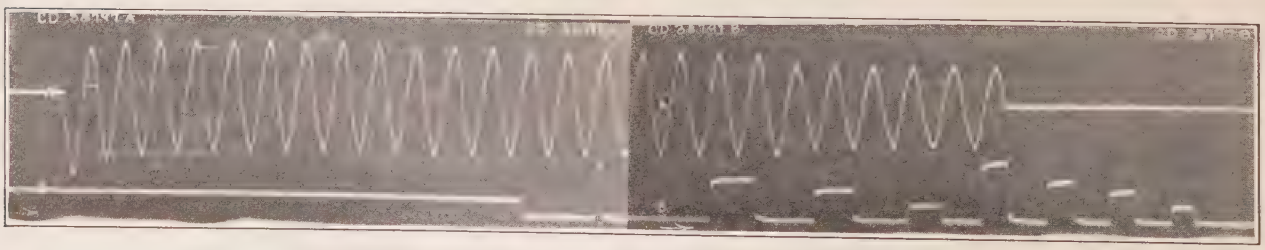

Fig. 7

falling off of current during arcing was due to breakers 106 and 308 opening before the short circuit was cleared by the test breaker.

44,000-Volt Tests

The tests at 44,000 volts were made both at Lock 12 and at Bessemer during January, 1922. The breakers

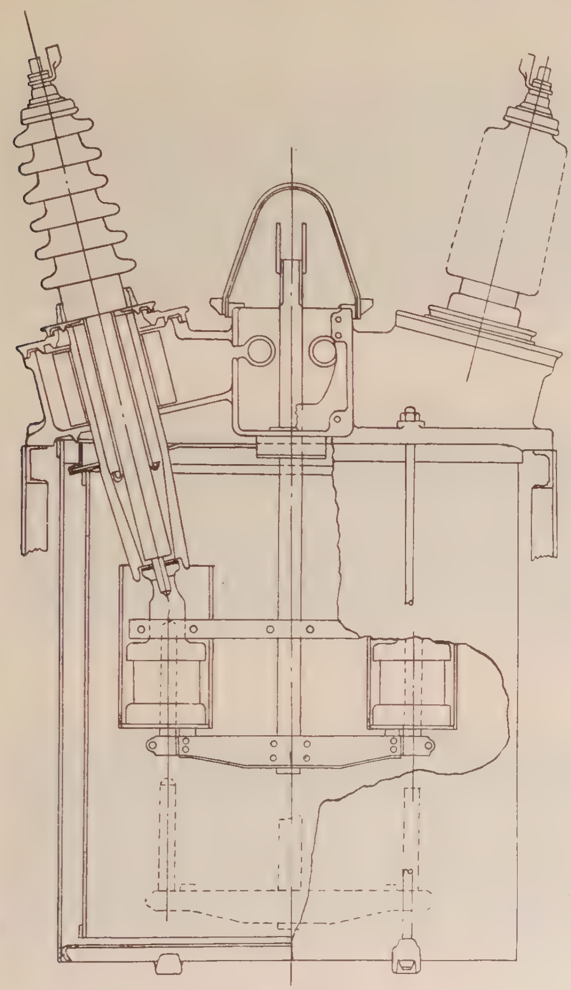

Fig. 8

tested were a 50,000-volt *F H K O*-36 *B* breaker, which had been arranged so that the explosion chamber contacts with which it is normally equipped could be replaced by plain break contacts. Both the plain break and explosion chamber contacts in this breaker were tested at Bessemer but only the explosion chamber was tested at Lock 12. The 50,000-volt explosion chamber breaker is shown in Fig. 8. The plain break contacts are shown in Fig. 9.

The 44,000-volt tests at Bessemer were made single phase by tapping the breaker onto phase No. 3 on the aluminum line from Bessemer to Magella and all tests were from No. 3 line to ground. All short circuits were closed by breaker No. 826 as shown on Alabama Power Company's diagram, Fig. 4.

On the lock 12 tests, the breaker tested was tapped onto the Montgomery circuits and the short circuits were thrown on by a transition model *K*-36-*A*, 50,000-volt breaker. All tests were made single phase from line to ground and in all cases both at Bessemer and Lock 12 the circuits from which the test line was tapped were carrying the ordinary commercial load. This latter fact should be kept in mind in considering the results of the test.

Oscillogram Fig. 10 shows an explosion chamber recorded when interrupting 1404 arc amperes. *A* is the voltage across the arcs and *B* the current interrupted. It should be noted that the arc records have all of the characteristics of the plain break arc and none of those of the explosion chamber arc. Fig. 11 shows another oscillographic record of an explosion chamber interrupting 1055 arc amperes and the remarks made above apply here also. Both of the above records were made at Bessemer. Fig. 12 shows an oscillogram of plain break contacts, when interrupting 1005 arc amperes and Fig. 13 shows the same breaker when interrupting 980

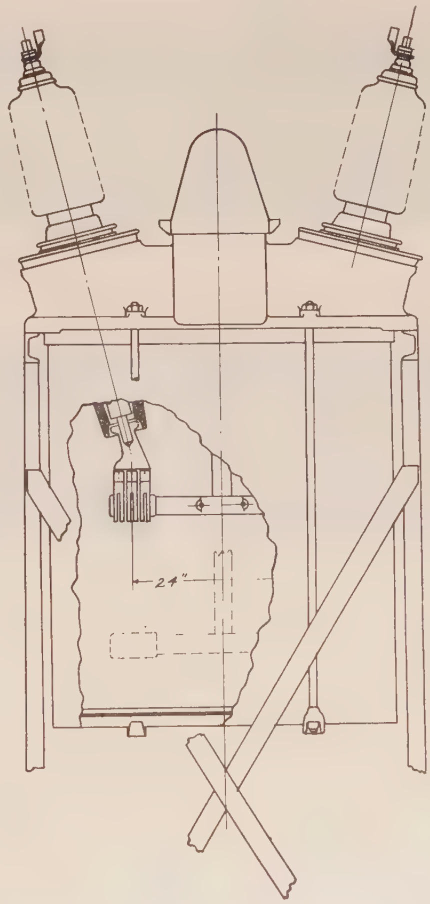

Fig. 9

arc amperes. Both the above oscillograms show the regular characteristics of the plain break arc and should be compared with the explosion chamber arcs of Figs. 10 and 11.

The results of the Lock 12 tests, as would be expected from the test conditions, did not differ from those made at Bessemer, and no especial remarks need be made

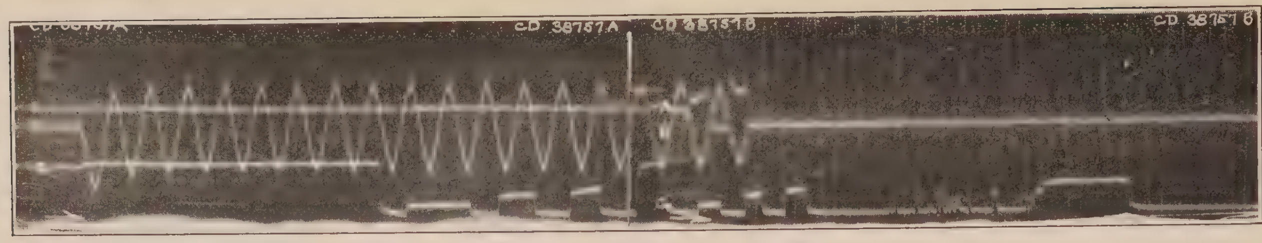

FIG. 10

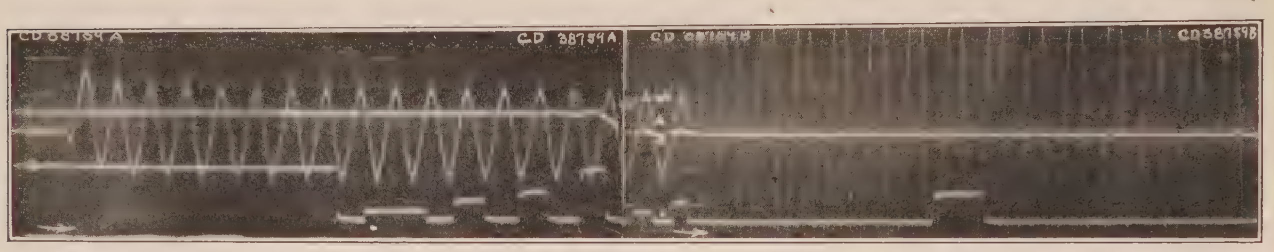

FIG. 11

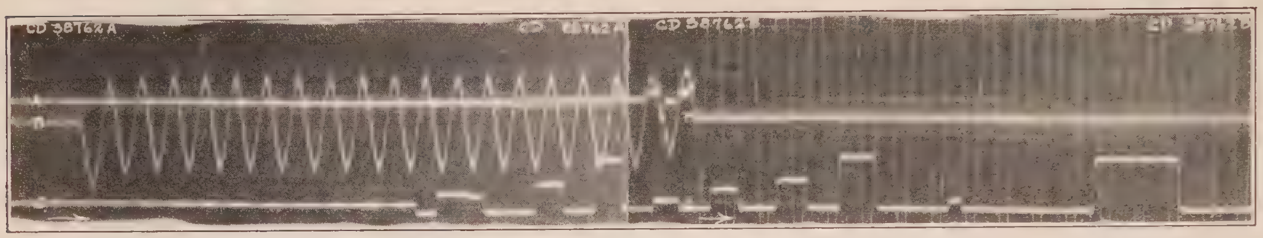

FIG. 12

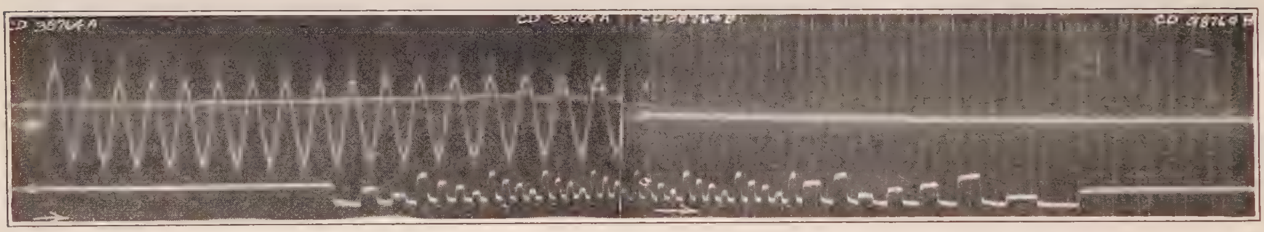

FIG. 13

THE 44,000-VOLT TESTS

Location	Amperes First Half Wave of Short Circuit	Amperes First Half Wave of Arc	Equiv. kv-a. Interrupted at Arc 3-Phase	Arc Duration Half Cycle (60-Cycle)	Speed Ft. Sec.	Oil Throw	Type of Contact
Bessemer	1082	805	61,300	4	6.2	None	Explosion Chamber
"	920	865	65,800	7	7.1	"	" "
"	1093	895	68,000	7	7.1	"	" "
"	1300	1040	79,000	8	6.85	"	" "
"	1138	1080	82,100	8	6.85	"	" "
"	1265	1055	80,200	9	7.4	"	" "
"	1220	1090	82,900	5	6.6	"	" "
"	1340	1090	82,900	8	..	.	" "
"	1340	1005	76,400	7	5.7	"	Plain Break
"	1130	1060	80,560	9	5.8	"	" "
"	1180	980	74,400	8	7.2	"	" "
"	1135	980	74,400	9	7.2	"	" "
"	980	980	74,400	2½	6.0	"	" "
"	1142	980	74,400	4½	6.66	"	" "
"	1185	980	74,400	7½	7.0	"	" "
"	474	405	30,750	..	..	..	" "
"	816	695	52,700	4½	6.65	"	" "
Lock 12		1100	83,600	8½	7.0	"	" "
" "		1065	81,000	7	6.9	"	" "
" "		1065	81,000	7½	7.3	"	" "

concerning them, except that they were stopped by the failure of a power transformer, failure taking place about 0.30 of a second after the test breaker had cleared the circuit. Inasmuch as the currents interrupted during these tests were comparatively small, the results, as would be expected under such conditions, do not show the full advantage of the explosion chamber. At such low currents the explosion chamber breaker functions very much as a plain break breaker.

In order to be efficient, the explosion chamber breaker must operate at high pressure in the chamber, hence a breaker designed to have an interrupting capacity of 3850 amperes at 44,000 volts, (the real interrupting capacity of the explosion chamber breaker tested) does not begin to show its remarkable current-interrupting capacity until approximately the safe limit of the plain break contact in the same tank is reached. Up to about that time it functions largely as a plain break breaker and is given the break distance required by such a breaker. From that point on, the gas pressure acting on the rod increases, the breaker speed increases, the arc becomes shorter and at maximum rating the arc duration is a minimum. The designer has full control of these characteristics and the breaker as a whole can be largely designed to meet any particular condition. The ability to control the speed of operation of the contacts by means of the gas pressure in the explosion chamber is of great operating value, as this pressure takes the place of accelerating springs, but offers no resistance to closing, as do the springs.

Conclusions

The tests herein reported indicate in the case of the 110,000-volt *K*-22 breakers that the interrupting ability of the breaker could be materially increased by the addition of explosion chambers. Although no data on the operation of the breakers without explosion chambers were obtained during the tests, the performance of such breakers was observed under actual service conditions prior to the test, so that a fairly accurate knowledge of their interrupting ability was obtained.

As has already been stated, the current available on the 44,000-volt tests was not sufficient to stress either the plain break or the explosion chamber breakers. It is not believed that the tests at Bessemer produced as severe a duty on the breaker as might be obtained under other conditions with the same current interrupted. This statement is based on the general knowledge of the factors affecting interrupting duty.

These factors, as determined by the system itself and the method of tests, operate in such a way that in my opinion the duty on the breakers was not maximum for the currents interrupted. Upon another system or in another location, the arc lengths might have been much longer at the same currents interrupted and that would mean more gas, greater pressures and decreased factor of safety.

All should realize that 1,000 amperes, for instance, interrupted at a definite voltage does not necessarily mean a definite stress to the circuit breaker. It does not mean a definite arc length nor a definite quantity of gas generated, as everything depends upon the existing conditions at the time of interruptions.

The manufacturer must necessarily design circuit breakers to safely rupture their rated current under the worst obtainable conditions. There are certain locations, however, where the conditions are such that the duty is light and it is reasonable for the power company to take advantage of such conditions in the breaker installations, provided it is understood that a change in conditions may make the breaker unsafe.

If any discounting of the absolutely safe interrupting rating of the breaker by the manufacturer is made by the power company it should be on its own responsibility, because it is the power company who has the knowledge of and control over the conditions.

It is my opinion that all primary breakers should be constructed so that they are safe with a definite minimum factor of safety under the worst obtainable conditions.

THERMAL CONDUCTIVITY METHOD OF ANALYZING GASES

The thermal conductivity method for gas analysis recently developed by the Bureau of Standards is described in Technologic Paper, No. 249.

Various gases conduct heat to different extents and this property is made use of in the method under consideration. A platinum wire of definite length is stretched along the axis of a cylindrical cell and is surrounded by a slowly flowing stream of the gas which is undergoing analysis. A duplicate wire is exposed to a standard or comparison gas. The two wires are connected in series in an electrical circuit and are supplied with current from a constant voltage source. Heat is generated by the passage of the current and the wires rise in temperature until the continuous dissipation of thermal energy is equal to the electrical energy supplied. By a proper construction of the cells, all loss of heat, except by conduction through the gases surrounding the wires, is reduced to a small proportion of the whole. In such cells the temperatures attained by the wires will depend mainly upon the thermal conductivities of the gases contained in the cells. Inasmuch as platinum has a high temperature coefficient of electrical resistance, the resistance of the wire, depending as it does upon temperature, will have a value corresponding to the thermal conductivity and therefore to the composition of the gas.

The apparatus used for comparing the resistance of the two wires is described, as well as a method by which a continuous record of the composition of a gas may be obtained.

High-Voltage Oil Circuit Breaker Tests,
Alabama Power Company System

BY J. B. Mac NEILL

Associate, A. I. E. E.

Electrical Engineer, Westinghouse Electric & Mfg. Co.

In conjunction with the Alabama Power Company, a series of 50 high-voltage oil circuit breaker tests was made during May and June of 1922. The Bessemer substation of the power company was chosen as the location for these tests due to the large power concentrations that were possible on short circuit, the possibility of maintaining system voltage under short circuit to the greatest extent and because it was felt that less interruption to service would occur if tests were made here than elsewhere.

As far as is known the Alabama Power Company was the first to conduct a comprehensive set of tests with necessary oscillograph apparatus and facilities for observation on 44,000 volts and 115,000 volts. Of the fifty tests made on Westinghouse breakers, 36 were made on 44,000 volts and fourteen were made on 115,000 volts. The maximum generating capacity

Fig. 1—Test Yard Set-up

connected to the system on 44,000-volt tests was 145,000 kv-a. The maximum generating capacity connected to the system on 115,000-volt tests was 188,000 kv-a. in addition to a tie with the Georgia Power System. The maximum power actually opened was 3660 amperes at 44,000 volts, and 2850 amperes at 110,000 volts, which give approximately 250,000 kv-a. three-phase at 44,000 volts, and 542,000 kv-a. three-phase at 110,000 volts. A glance at the power system set-up and the amount of generating apparatus connected will show that these tests were made under power conditions comparable to those on the larger of the systems throughout the country.

Three types of circuit breaker were tested on 44,000 volts, these being the old 45,000-volt type *G B* breaker, the modern 50,000-volt *G*-11, and the modern 73,000-volt *G*-11 breaker. Two breakers were tested on 110,000 volts, namely the 115,000-volt modern *G*-11 breaker and the old 110,000-volt type *G A* breaker. It was originally intended to test the 115,000-volt type *G*-2 breaker, but this breaker was in active service in the substation and as the maximum power available did not tax the capacity of the lighter breakers, it was not felt necessary to test the *G*-2 breaker. All breakers tested were of the outdoor type, electrically operated with plain break contacts, and equipped with ordinary accelerating devices.

The method of making the test has been described in another paper but we will mention that the current

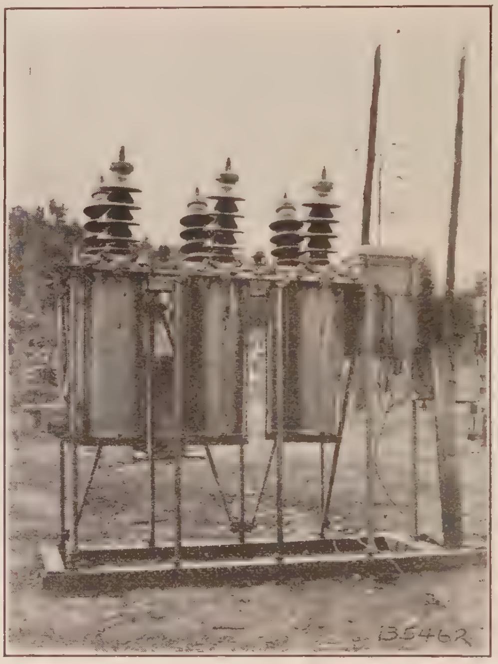

Fig. 2—50,000-Volt G-11 Breaker

transformers used with the oscillographs were given a special calibration test at the factory after the tests were over, and all current values have been corrected accordingly.

Tests on 50,000-Volt Type *G*-11 Oil Breaker

Table I gives a summary of the test data on this breaker. Fig. 2 shows the breaker as arranged for test. Fig. 3 shows the standard type of contact used. This breaker is equipped with baffled vents and on heavy short circuit threw some oil through these vents. While there is nothing of particular interest in connection with the tests on the standard breaker,

Presented at the Spring Convention of the A. I. E. E., Birmingham, Ala., April 7-11, 1924.

TABLE I
SUMMARY OF TESTS ON
50,000-Volt G-11 Breaker
on 44,000 Volts

Test No.	Opened Circuit	A		B		C	
		Current opened 1-st. Arc. Cycle r. m. s. Amps.	Cycles of Arcing	Current opened 1-st. Arc. Cycle r. m. s. Amps.	Cycles of Arcing	Current opened 1-st. Arc. Cycle r. m. s. Amps.	Cycles of Arcing
1	O. K.	..	..	..	..	1350	5.5
2	O. K.	2050	6.5	1870	4.5	1670	6.5
3	O. K.	1840	4.5	1910	..	1860	3.5
4	O. K.	1570	5.5	1935	..	1775	5.0
5	O. K.	2120	6.5	2650	..	2520	5.5
6	O. K.	2040	4.5	2650	..	2580	10.5
7	O. K.	1140	3.0	..	..	..	..
8	O. K.	2470	..	..	..	2585	6.5
9	Yes (Split Tank)	3140	8.0	3600	..	..	..
45	O. K.	2370	4.0	2700	..	..	..
46	No Test	..	..	..	..	..	..
47	O. K.	..	..	2800	..	2580	..

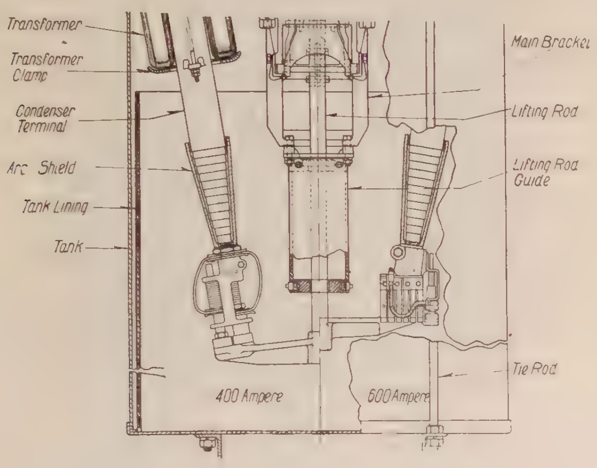

FIG. 3—50,000-VOLT G-11 CONTACTS
73,000-VOLT G-11 CONTACTS

test No. 9 on a special arrangement of the breaker may be of some interest. For this test the breaker had been equipped with one muffler per pole, the idea being to prevent an oil spray coming through the vent. This test represented practically the maximum available on the 44,000-volt system, the oscillograph reading showing 3140 amperes on the *A* phase, and 3600 amperes on the *B* phase. The back pressure in the tank due to the muffler caused the *A* phase tank to split along the bottom seam as shown in Fig. 4. The conclusion to be drawn therefore from the application of mufflers to relatively lightly constructed high-voltage breakers is that a point in rupturing capacity is reached where the internal stresses caused thereby are beyond the strength of the breaker. The breaker when equipped with mufflers is not capable of relieving itself as readily as with the open vent and as a result the breaker is damaged at a current below what it would have opened with the open vent. This statement has no reference to the application of mufflers to breakers constructed to withstand high internal pressures.

Deterioration of the contacts was limited to rather slight pitting of the arcing tips and there was no damage to the tank lining. Several specimens of oil were taken from tanks during the test and they indicated that after the oil had settled a while it still retained insulating value suitable for further service, being in general well up towards normal dielectric strength.

TESTS ON 73,000-VOLT TYPE *G*-11 BREAKERS

This breaker is rated at 2400 amperes at 73,000 volts

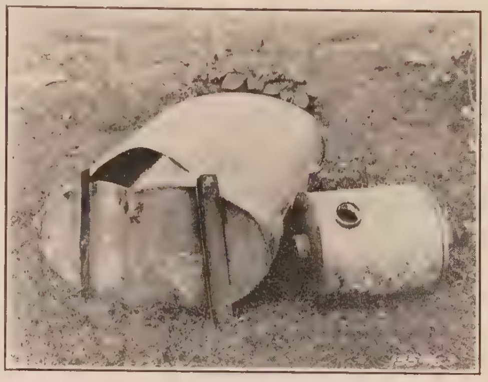

FIG. 4—MUFFLER AND TANK—50,000-VOLT G-11 BREAKER

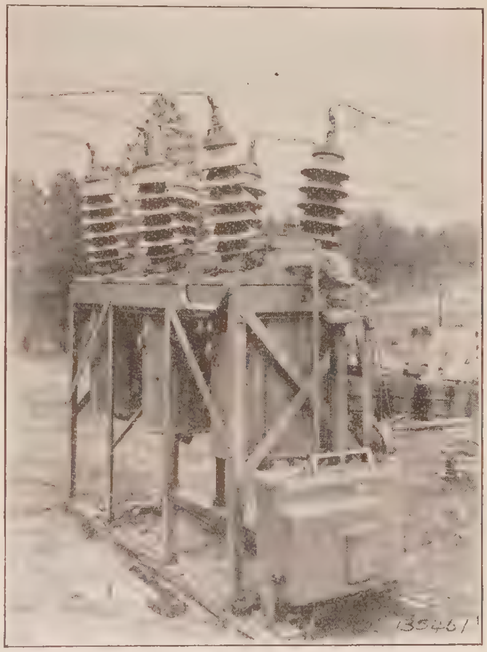

FIG. 5—73-KV. G-11 BREAKER

and the maximum current opened on it was 3660 amperes at 44,000 volts. The breaker is shown in Fig. 5 and contact construction is shown in Fig. 3. A summary of the tests on this breaker is given in Table II. Three of the tests were single interruptions of a three-phase ungrounded short circuit and the last two formed a duty cycle consisting of two interruptions at a two minute interval on a three-phase grounded short circuit. On test No. 43 considerable oil was thrown

TABLE II
SUMMARY OF TESTS ON
73,000-Volt G-11 Breaker
on 44,000 Volts

Test No.	Opened Circuit	A		B		C	
		Current opened 1-st. Arc. Cycle r. m. s. Amps.	Cycles of Arcing	Current opened 1-st. Arc. Cycle r. m. s. Amps.	Cycles of Arcing	Current opened 1-st. Arc. Cycle r. m. s. Amps.	Cycles of Arcing
10	O. K.	See test No. 9 for Approximate Currents					
11	Yes						
12	O. K.	3300	12.5	3660	..	3330	12.0
43	Yes	3000	13 0	3220	..	2840	12.0
44	O. K.	2680	..	3140	..	2740	8.0

from all tanks, probably amounting to as much as ¼ in. from each tank. This was due apparently to a partial gas explosion in the top chamber which forced oil between the frame and the tank. On the succeeding test two minutes later, the oil throw was much less, probably a half gallon total from all three tanks.

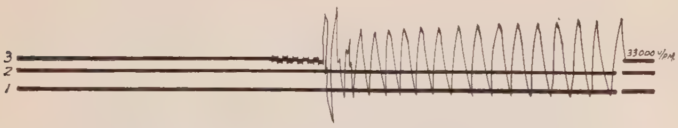

Fig. 6—Showing Voltage Reestablishment on 44,000-Volt System with No Ground Near Point of Short Circuit

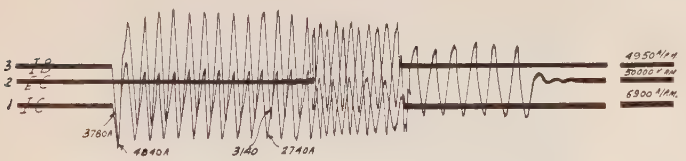

Fig. 7—Showing Voltage Reestablishment on 44,000-Volt System with Ground at Short Circuit

On the other tests the breaker threw slight amounts of oil.

In connection with the 44,000-volt tests made on this breaker with the short circuit ungrounded. Fig. 6 is of interest as showing a typical voltage reestablishment under these conditions, of approximately 50 per cent overvoltage. With the short circuit ungrounded, the only ground on the 44,000-volt power system was through a single transformer bank at the Lock No. 12 generating station. In contrast to this result, note the oscillogram shown in Fig. 7 taken during test No. 44 with the system grounded at the short circuit in addition to being grounded back at the generating station and with approximately the same power at short circuit as in the oscillogram preceding. The complete absence of overvoltage surge with the system thoroughly grounded is of particular interest.

Tests on 45,000-Volt *G B* Breaker

The type *G B* breaker shown in Fig. 8 is an old breaker that had been on the Alabama Power Company's line since approximately 1913 and it was desirable to find out its rupturing capacity as it stood, and with some improvements. The contact construction of this breaker is shown in Fig. 9 and the test results are given in Table III.

The breaker was tested on 44,000 volts, 60 cycles, three-phase, with grounded neutral, using a maximum

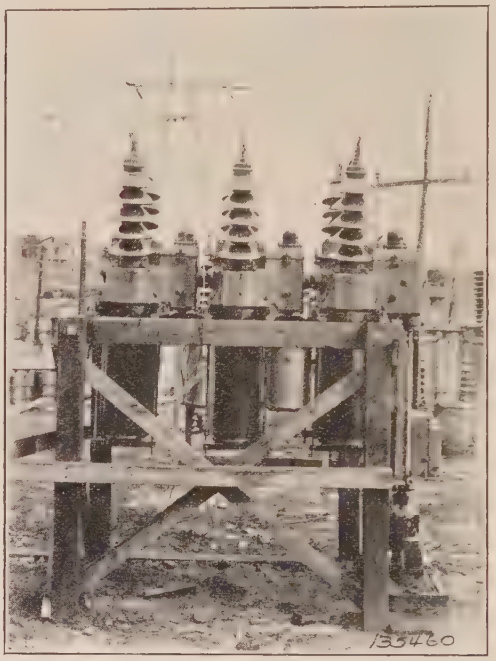

Fig. 8—45,000-Volt G. B. Breaker

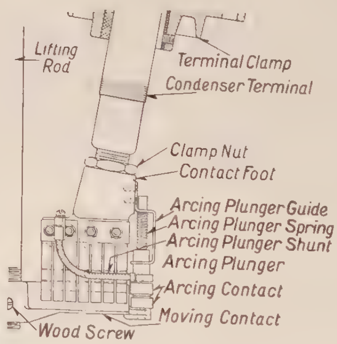

Fig. 9—G. B. Breaker Contacts

total connected generating capacity of 139,000 kv-a. The breaker without modifications opened up 2000 amperes with the short circuit ungrounded with considerable emission of smoke and throwing of oil at this value.

The breaker was then altered by the substitution of some improved contact details and tested by seven single interruptions of three-phase short circuits, mostly grounded, one interruption of a single-phase short

TABLE III
SUMMARY OF TEST ON
GB—45,000-Volt Breaker
on 44,000 Volts

Test No.	Opened Circuit	A Current opened 1-st. Arc. Cycle r. m. s. Amps.	A Cycles of Arcing	B Current opened 1-st. Arc. Cycle r. m. s. Amps.	B Cycles of Arcing	C Current opened 1-st. Arc. Cycles r. m. s. Amps.	C Cycles of Arcing
13	O. K.	..	..	..	..	784	4.0
14	O. K.	740	4.5	..	..	..	..
15	..	..	..	..	..	.	.
16	O. K.	734	5.0	..	.	..	
17	..	..	..	..	..	..	..
18	O. K.	..	..	..	..	805	4.0
19	Yes	2260	6.5	1870	..	1710	7.0
20	O. K.	1495	4.5	..	..	..	.
21	O. K.	1820	7.0	2060	..	1850	..
22	O. K.	1760	7.0	1800	..	1680	..
23	O. K.	1010	3.5	..	..	..	..
35	O. K.	2230	8.0	2500	..	2465	7.5
36	O. K.	..	..	2700	..	2660	10.0
37	O. K.	..	..	2820	..	2660	7.0
38	O. K.	2595	13	..			.
39	Bkr. did not close	2770	..	2875	.		..
40	O. K.	2825	..	2980	8	.	.
41	Yes	2670	..	2935	..	.	..
42	Did not open	2740	..	2950	.	..	..

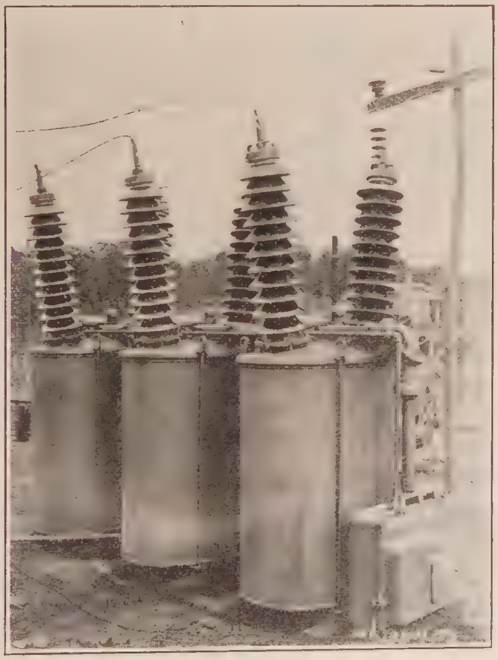

FIG. 10—115,000-VOLT G-11 BREAKER

circuit to ground and one repetition on a two-phase short circuit to ground on a duty cycle consisting of two interruptions at a two minute interval, starting from the closed position. A maximum of 2900 amperes was interrupted with more or less throwing of oil on the various tests.

Two attempts were made to close this breaker against short circuit, but they were not successful as the arrangements of the control wiring in connection with the oscillograph operation could not be properly worked out in the limited time. In the last one of these attempts, after the breaker had opened several short circuits, and the oil was at a relatively low value imperfect contact in the breaker caused heavy arcing and emission of flame. The breaker was mechanically undamaged except for burning on the arcing tips.

TESTS ON 115,000-VOLT TYPE *G*-11 BREAKERS

This breaker is shown in Fig. 10 and its contact construction shown in Fig. 11 while the tabulation of test data is given in Table IV. This breaker was tested on a 115,000-volt, 60-cycle, three-phase, grounded neutral system, using a maximum total connected generating capacity of 188,000 kv-a. in addition to a tie in with the Georgia Power Company which transmitted a relatively small amount. Two single inter-

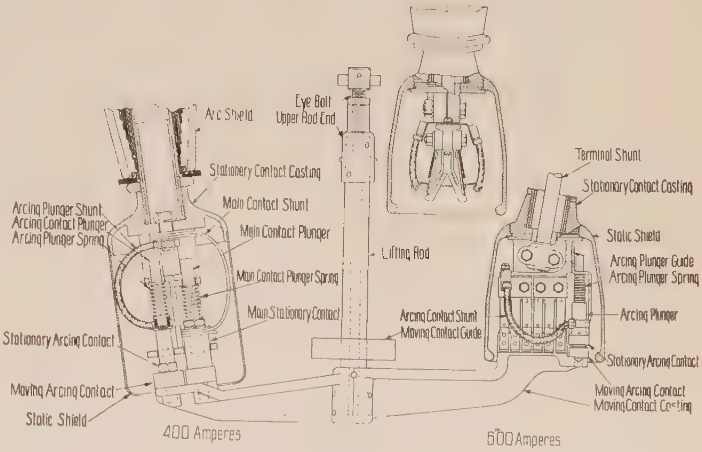

FIG. 11—115,000-VOLT G-11 CONTACTS

TABLE IV
SUMMARY OF TESTS ON
115,000-Volt G-11 Breaker

Test No.	Opened Circuit	A Current opened 1-st. Arc. Cycle r. m. s. Amps.	A Cycles of Arcing	B Current opened 1-st. Arc. Cycle r. m. s. Amps.	B Cycles of Arcing	C Current opened 1-st. Arc. Cycle r. m. s. Amps.	C Cycles of Arcing
24	O. K.	894	4.0	900	5.0	..	..
25	O. K.	985	2.5	1030	..	1060	..
26	O. K.	1470	3.0	..	..	..	..
27	O. K.	1495	5.0	1540	..	1080	..
28	O. K.	1810	5.0	1850	..	1790	..
29	O. K.	2030	7.0	..	..	2225	..
30	O. K.	2500	7.0	..	..	..	..
48	O. K.	..	..	..	..	2640	13.0
49	O. K.	..	..	..	..	2850	8.0

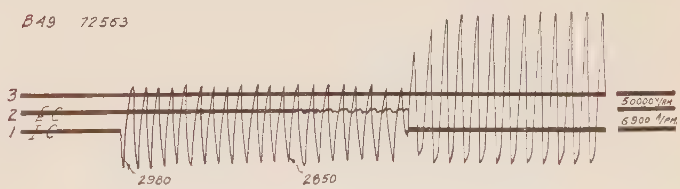

FIG. 12—115,000-VOLT G-11 BREAKER. OPENING 2850 AMPERES AT 115,000 VOLTS

ruptions were performed on a three-phase grounded short circuit; two on a short circuit from one phase to ground, one duty cycle consisting of a single interruption of a three-phase short circuit to ground followed at a two-minute interval by an interruption of a single-phase short circuit to ground; and one duty cycle consisting of three single interruptions at two-minute intervals of successive three-, two- and single-phase short circuits to ground in the order stated.

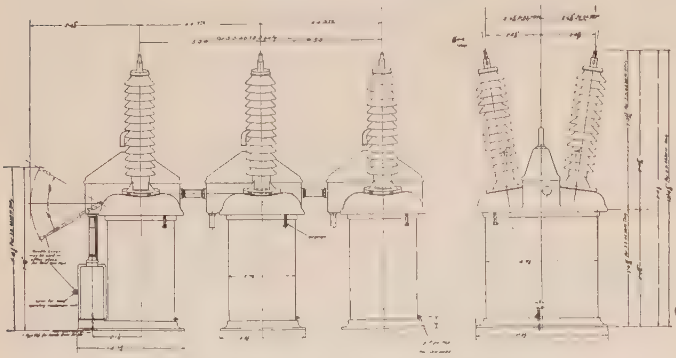

Fig. 13—G. A. 110,000-Volt Breaker

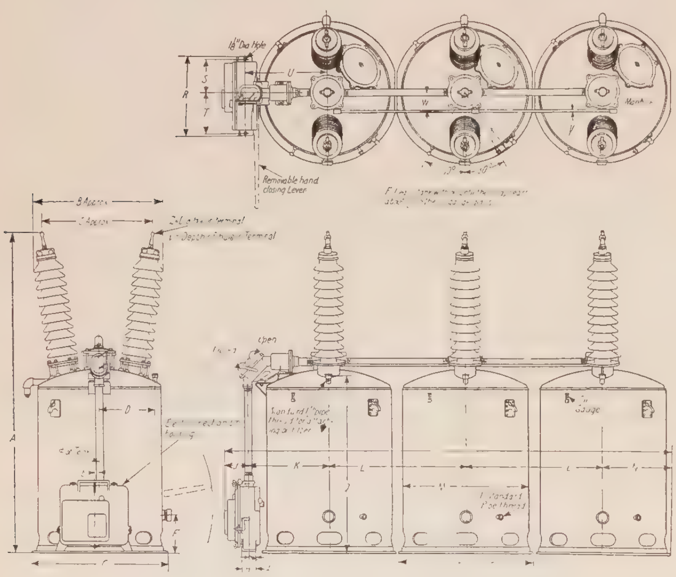

Fig. 15—115,000-Volt G-2 Breaker

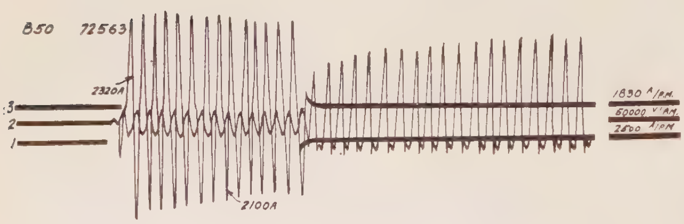

Fig. 14—110,000-Volt G. A. Breaker. Openihg 2100 Amperes at 115,000 Volts

The maximum current interrupted was 2850 amperes in a single-phase short circuit to ground. At the end of the test the oil in the tanks was clear and the contacts in good condition. No oil was lost in any of these tests with the possible exception of a few drops at a terminal flange or so. These tests serve to emphasize the adequate construction of this breaker in every way and also indicate that a thoroughly grounded system such as this 110,000-volt system gives easier switching duty than one that is ungrounded or imperfectly grounded. Fig. 12 shows an oscillogram taken in test No. 49 with the breaker opening the maximum single-phase short circuit to ground that was possible on the system, or 2850 amperes in the arc.

Tests on 110,000-Volt *G A* Oil Breaker

The 110,000-volt type *G A* breaker shown in Fig. 13 was purchased in 1913 and has been continuously in operation at the Magella substation of the Alabama Power Company. This breaker had originally an interrupting capacity of approximately 1900 amperes at 110,000-volts and was tested on the 115,000-volt, 60-cycle, three-phase, grounded neutral system, using a maximum total connected generating capacity of

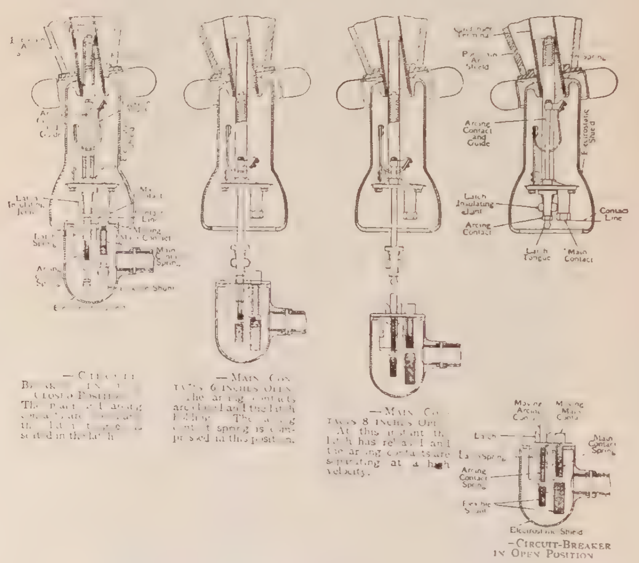

Fig. 16—High-Speed Contacts for 115,000-Volt G-2 Contacts

169,000 kv-a. The breaker performed three single interruptions and one duty cycle consisting of two interruptions at a two-minute interval, on a three phase grounded short circuit. The maximum current interrupted was 2100 amperes. The only sign of distress was a slight leakage of oil from around the terminal clamps in one or two tests. It was not possible to determine the number of cycles of arcing in this breaker as the oscillograph equipment was located 14 miles away at Bessemer and the drop through the line from the point where the potential transformers were connected was so large as to make impossible the detection of the initial cycles of arcing. However, referring to Fig. 14 which shows the breaker opening a dead short circuit with 2100 amperes in the arc, and making allowance for the operating time of the mech-

anism, we find that the arc probably endured for 10 cycles.

115,000-Volt Type G-2 Breaker

As a matter of interest Fig. 15 shows the 115,000-volt type *G*-2 breakers located in the switch yard at the Bessemer station. Fig. 16 shows the contruction of the high-speed contacts used with this high-power breaker. Due to limitations of power available on short circuit it was not thought necessary to test this breaker and it is felt that in the near future arrangements can be made for such a test. The high speed of contact separation on the *G*-2 breaker increases its rupturing capacity greatly by reducing the number of of arcing. Its rupturing capacity is further increased by the mechanical strength of structure which consists of a boiler iron tank with riveted and welded top and botton domes.

Recent Developments in Kilovolt-Ampere Metering

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Associate, A. I. E. E.
Westinghouse Elec. & Mfg. Co.

Review of the Subject.—*The problem of measuring kilovolt-amperes power factor has received considerable attention from the rate maker and the electrical engineer during the last few years. This paper describes two late developments in kv-a. demand meters. One meter is of the indicating type and indicates total kw. hours, kw. demand and kv-a. demand. The other meter is of the recording type and gives a record of kw. demand kv-a. demand, kw. hours, and kv-a. hours.*

THE problem of measuring voltamperes presents difficulties to the electrical engineer which are not as readily solved as might first be suspected. The difficulties lie in the fact that to measure the product of volts and amperes through the complete range of lagging and leading power factors requires either a shifting of the phase relation between the voltage and current in order to measure the quantities by the wattmeter principle, or the measurement of the two components, reactive and power, of the voltamperes which then must be added vectorially to obtain the apparent power.

Assuming that there is a demand for voltampere measuring devices, without considering the scope or possibilities of such a demand, it is the purpose of this paper to discuss the design of two recent developments in kilovolt-ampere-demand meters. The meters described are of the type which combines the registration of two demand meters. While each kv-a. meter employs the same method of obtaining the energy and reactive components, different schemes are used to obtain the vector sum of the components, or in other words, different mechanical devices are used to obtain the "square root of the sum of the squares."

The methods of measuring watthours are widely known because of common application; the measurement of reactive voltampere hours is not so generally used, and hence data concerning the various methods are not available from as great a number of sources. A complete report on the subject will be found in the 1921 Report of the National Electrical Light Association Meter Committee.

Of the various possible methods of measuring the reactive component probably the most outstanding one is the "Compensator" or auto transformer method. This method facilitates the measurement because it uses a standard watthour meter which is calibrated as a watthour meter. Since this method is preferred in connection with the use of the new volt-ampere meters a brief analysis is given here.

To measure the reactive component with a watthour meter it is necessary to connect the meter so that the

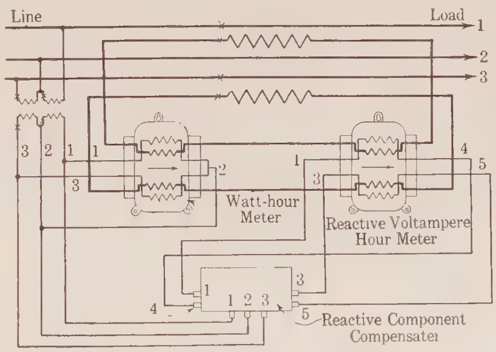

Fig. 1—Connections for Measuring Voltampere Hours with a Reactive Component Compensator

potential impressed on the voltage coil is in quadrature to the voltage used for the watthour measurement. The reactive component compensator gives the quadrature relation and proper magnitude of voltages for use with commercial watthour meters by using two small auto-transformers with suitable taps and connections. In making the connections for reactive component measurement it is necessary to take into consideration the phase rotation since the direction of rotation of the

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meter changes with phase rotation as well as lagging and leading power factors.

The vector diagram for the connections which are shown in Fig. 1 are given in Fig. 2.

It will be observed in the diagrams that the small auto-transformers have taps at 57.7 per cent and 115.5 per cent of the primary winding and that the voltages thus obtained are combined so that the resultant

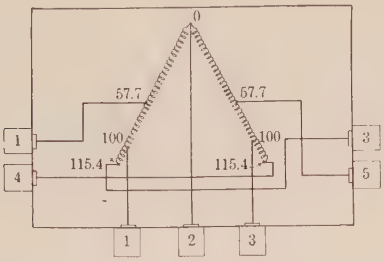

Fig. 2—Internal Connection of Reactive Component Compensator

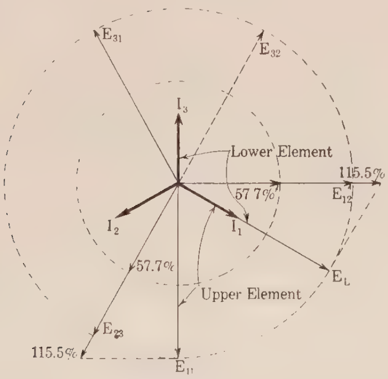

Fig. 3—Vector Diagram of Reactive Compensator Voltages

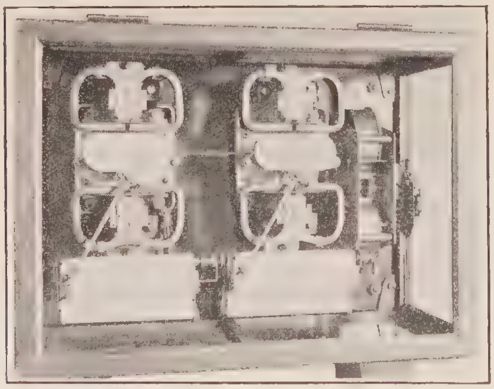

Fig. 4—Duplex *R A* Demand Meter

voltages are equal in magnitude to the impressed voltages but are in quadrature to the impressed voltages. The voltage used on the upper element of the R.Va.H meter is 57.7 per cent of $E12$ plus 115.5 per cent of $E23$, which is equal to the voltage $E12$ but is 90 deg. behind this voltage. Likewise the voltage on the lower element is equal to the voltage $E32$ but lags it by 90 deg.

It is manifest therefore from the brief description of the reactive voltampere hour meter that it is possible to measure the reactive component practically as easily as the energy component. However the obtaining of the apparent energy or the "square root of the sum of the squares" presents a more difficult problem for which a number of solutions have been offered. Two of the most recent developments are described below.

Type *RS* Kv-a Demand Meter (Pantagraph Type)

It should be understood that watthour demand meters can be substituted for the two meters in Fig. 1.

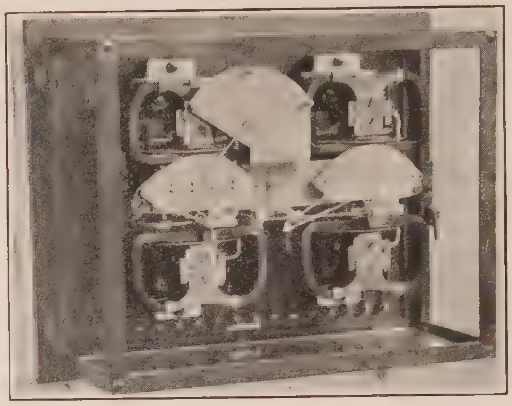

Fig. 5—Type *R S* Kilovolt-Ampere Demand Meter

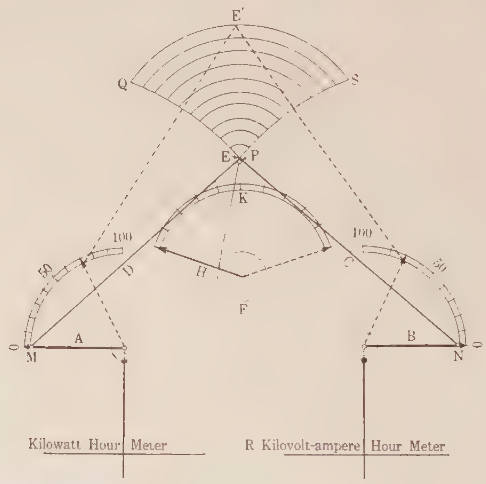

Fig. 6—Schematic Plan of Indicating Mechanism of the Type *R S* Kv-a. Meter

Fig. 4 shows the arrangement of two demand meters in one case and operated by one clock so as to obtain simultaneous records. When two demand meters are so used it is possible to obtain directly or by calculation the following data:

1. Kw. hours.
2. R kv-a. hours
3. Apparent power factor at which 1 and 2 were obtained.
4. Maximum kw. demand
5. Maximum *R* kv-a. demand.

6. Apparent power factor at which 4 and 5 were obtained.

7. Kw. demand during any time interval on chart.

8. *R* kv-a. demand during any time interval on chart.

9. Apparent power factor for 7 and 8.

While each of these items is valuable in studying the load history of an installation, all are not essential in billing for electric service. In most of the present rate schedules which take in consideration power factor and kv-a., the important items are kw. hours, maximum kw. demand, maximum kv-a. demand and power factor at time of maximum demand. The type *R S* meter shown in Fig. 5 indicates the kw. hours, the maximum kw. demand and the maximum kv-a. demand. Although the meter has been developed only in the indicating type the principle employed is equally applicable in a graphic type of meter similar to the type *R I* described later in this paper.

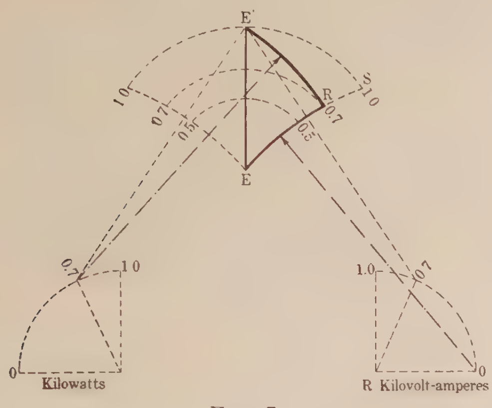

FIG. 7

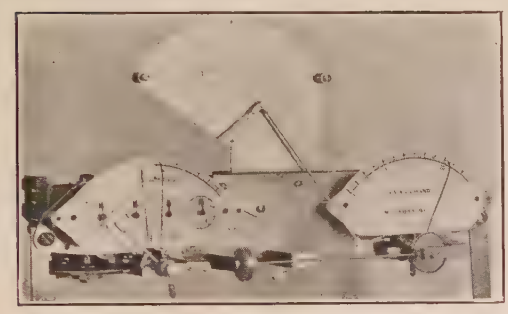

FIG. 8—FRONT VIEW OF REGISTER FROM TYPE *R S* METER

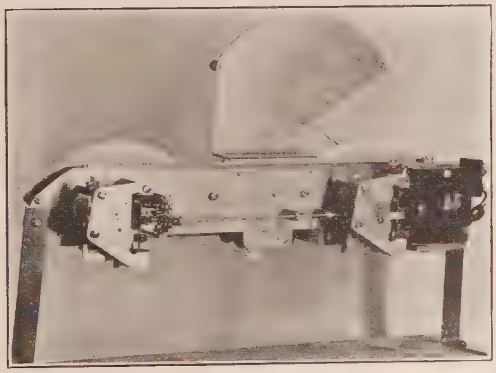

FIG. 9—REAR VIEW OF THE REGISTER FROM TYPE *R S* METER

The principle employed in the type *R S* meter is a pantagraph arrangement of levers operated by the kw-h. meter and *R* kv-a. *H* meter. A schematic diagram of the operating principle of the meter is given in Fig. 6. *A* and *B* represent pointers for demand registers placed on the kw-h. meter and kv-a. *H* meter. These pointers are placed to the additional use of acting as levers in the pantagraph arrangement of levers *A*, *B*, *C*, and *D*, which are pivoted at *M*, *N* and *E*. During the operation of the meter the point *E* moves over the surface *E S E′ Q*, the path of the point depending upon the relative movement of the levers *A* and *B*. A cord is attached to the point *E* and passed through a guide (*P*) to a pulley (*F*) on which the kv-a. pointer (*H*) is mounted. The movement of the point *E* to some point such as *E′* advances the kv-a. pointer (*H*) proportional to the length of cord *E E′*. Now the length of *E E′* is equivalent to the hypothenuse of a right triangle whose sides are equivalent to the indications of the kw-h. and *R* kv-a. *H* meters respectively.

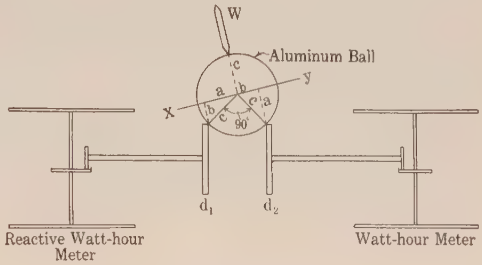

FIG. 10

Radii *a* and *b* to axis of rotation are proportional to respective speeds of wattmeters. Wheel *W* is therefore of a speed proportional to *c*, which is $\sqrt{a^2 + b^2}$ and is therefore proportional to kv-a. *W* is geared to the pointer in meter charts; it also drives dials which register kv-a. hours.

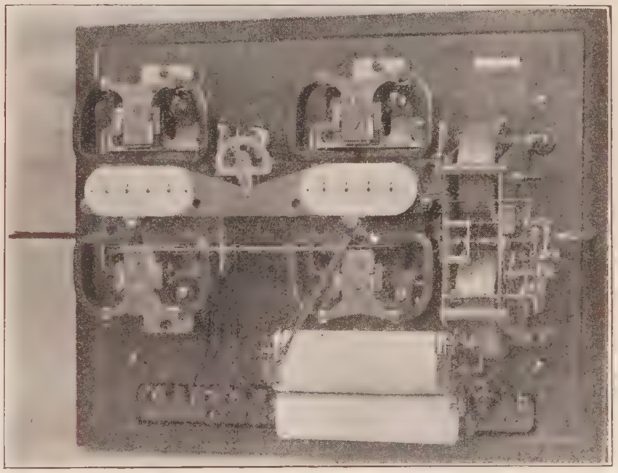

FIG. 11—TYPE *R I* KV-A. DEMAND METER

This is more clearly illustrated in Fig. 7 where the point *E* in moving to *E′* may be considered as moving along the path *E* to *R* to *E′*. The base of the right

triangle (E-R) is proportional to the indication of the kw-h. meter while the altitude ($R\,E'$) is proportional to the indication of the R kv-a. H meter. If it is assumed that the reactive component is zero, the point E would move along the line $E\ R$ to the point R which would give a kv-a. indication equal to that of the kw. register, or in other words, a unity power factor indication. Each arc drawn on the surface $Q\ E\ S$ with E as center represents a given value of kv-a. The various radial

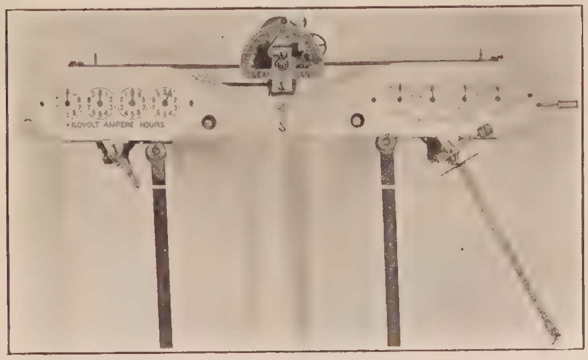

Fig. 12—Type *R I* Demand Meter, Front View of Register

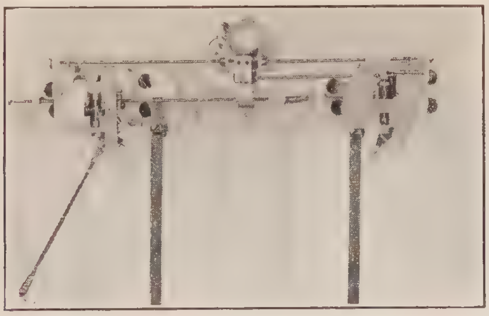

Fig. 13—Type *R I* Demand Meter, Rear View of Register

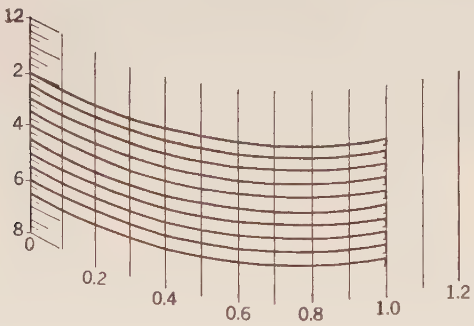

Fig. 14—Unity Power Factor Record

lines such as $E\ S$ - $E\ E$ and $E\ Q$ represent power factor. Hence, the apparent power factor for any kv-a. indication can be determined by observing the position of point E. The approximation of the true kv-a. by the pantagraph method used in the Type $R\ S$ meter depends upon the choice of the length and location of levers and the angles of deflection of the levers. In the design of the meter these variables have been selected so that the maximum difference between the true and the indicated kv-a. demand is well within the accepted limits of accuracy for watthour meters.

The construction of the $R\ S$ meter utilizes commercial polyphase watthour meters for the meter elements and parts of commercial demand registers in the construction of the register. The time interval is determined by the same type of small induction motor as in the commercial form of demand register and the gravity resetting of demand pointers is arranged similar to the same device. Figs. 8 and 9 show front and rear views of the kv-a. demand register.

Type *R I* Kv-a. Demand Meter (Ball Type)

Another method of combining reactive and power components of volt-amperes make use of a valuable

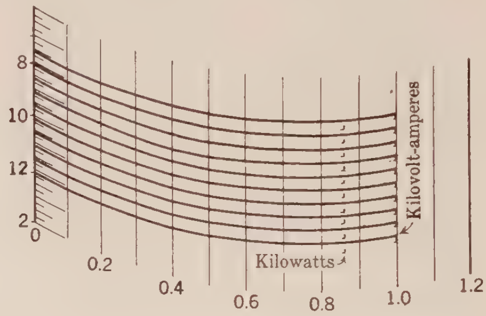

Fig. 15—85 per cent Power Factor Record

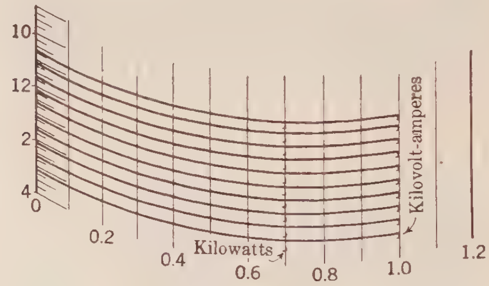

Fig. 16—70 per cent Power Factor Record

property of a sphere driven by two disks and driving a third disk in which combination the angular motion of the third disk is the vector sum of the motion of the two disks. Referring to Fig. 10, the aluminum ball is supported by disks d-1 and d-2 running in the same direction at varying speeds. The ball assumes an axis of rotation $X\ Y$ such that perpendiculars a and b are proportional to the respective speeds of the disks. The disks are spaced 90 deg. apart so that the two triangles a-b-c are similar and equal. It is evident that in the right triangle a-b-c that c the radius of the sphere is the hypotenuse of the triangle and is therefore the vector sum of a and b. In the type $R\ I$ voltampere meter d-1 and d-2 are driven respectively by reactive and watthour meters and a wheel W is mounted in a movable frame so that it rolls on a great circle of the sphere

whose plane is always perpendicular to the axis $X\ Y$ and the angular motion of W is then proportional to the radius C of the sphere.

The frame which carries W is arranged so that it can swing about an axis passing through the center of the ball perpendicular to the plane in which $X\ Y$ moves.

Through suitable gearing the integrated angular motion W is communicated to the pen and leaves a record on the paper chart. The pen is reset at regular intervals as in other recording demand meters. It is

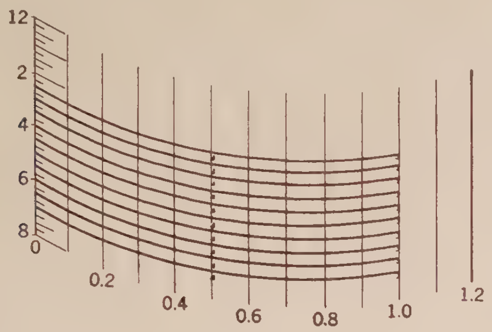

Fig. 17—50 per cent Power Factor Record

obviously desirable to have both kw. and kv-a. demands readings on one chart, and this was accomplished by arranging a mechanism on the kw. element which causes the pen to hesitate a fraction of a section during the process of resetting and make a mark on the paper which indicates the kw. demand. Since kv-a. is always greater than kw. there is no possibility of this stop advancing ahead of the kv-a. mechanism.

Figs. 14 to 18 illustrate the records obtained under

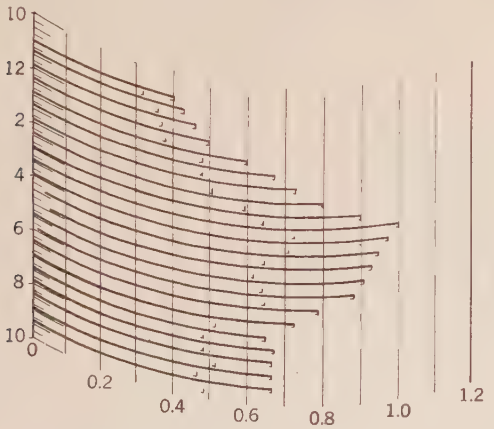

Fig. 18—Constant Power Factor and Variable Load

several conditions of power factor. In Fig. 14 with 100 per cent power factor the kv-a. and kw. indications are coincident and show a demand of 1000 watts for the time interval which was 15 minutes on the particular meter used on these tests. In Fig. 15 the kv-a. demand is still approximately 1000 watts but as the power factor is approximately 85 per cent the kw. record is reduced to about 850 watts. In Figs. 16 and 17 the kw. demand is still less with a corresponding power factor of 70 per cent and 50 per cent. Fig. 18 is a record of gradually decreasing demand with a constant power factor of about 70 per cent. The right hand dials are arranged to register kw. hours and the left hand dials kv-a. hours, hence the apparent power factor for the month can be obtained. Referring again to Fig. 10 a/c is the ratio of kw. to kv-a. and is the cosine of the angle through which moves the frame which carries the wheel W, therefore a pointer mounted on this frame will give an indication of the power factor at any time.

From the above it is manifest that the meter gives a direct reading of indicated power factor, total kw. hours, total kv-a. hours, and kw. and kv-a. demand for the time interval. The power factor for any time interval particularly at the time of maximum demand can be readily obtained by inspection of the chart.

MEASUREMENT OF LOW RESISTANCES BY MEANS OF THE WHEATSTONE BRIDGE

The Bureau of Standards has recently issued a paper describing a method for measuring resistances as low as 0.01 or even 0.001 ohm by means of the Wheatstone bridge.

Many writers of textbooks on this subject have held that it is impossible to measure low resistances, say 0.1 ohm or less, with the Wheatstone bridge, yet this is often the only apparatus at hand with which the resistance of a shunt, a reel of cable, or a sample for conductivity test can be determined.

When using the Bureau's method, the resistance must have separate current and potential terminals, and the current terminals must have very low resistance. In connecting the resistance to the bridge, the current terminals are connected to the binding posts for the unknown resistance. One of the battery wires runs to one of the potential terminals instead of to the usual binding post, and one of the galvanometer wires is connected to the other potential terminal.

DRY BATTERIES FOR RADIO USE

Among the standard assemblies of dry cells adopted by the conference held at the Bureau of Standards, 1921, there were included two batteries for radio use. Since that date the demand for dry batteries for radio purposes has increased very greatly and the conditions of use have been considerably changed. It appears desirable, consequently, to revise the specifications for the performance of such batteries. In anticipation of another conference to consider this problem the Bureau and a number of battery manufacturers have been carrying out extensive tests in order to determine the type of performance tests to be established and proper numerical values for these requirements. The matter has also been taken up by a committee of the American Electrochemical Society on which the Bureau is represented. It is planned to call a conference of dry cell manufacturers and others interested to meet at the Bureau within the next few months.

A Novel Alternating-Current Voltmeter

BY LEON T. WILSON

Formerly Connecticut Company Research, Fellow, Yale University

Review of the Subject.—*This paper describes an improved thermo-voltmeter, which may be used at all frequencies up to and including 1,000,000 cycles. This meter retains the usual high sensitivity of thermovoltmeters so that it requires a very small current—for full scale deflection about 2 milliamperes.*

At present it is made in ranges from 1 to 20 volts inclusive. Higher voltage ranges can be made but probably at the expense of lowering somewhat the upper limit of frequency at which the instrument is still accurate.

* * * * *

History of Development

THE voltmeter to be described was first devised in 1918 to meet the requirements of a particular problem[1]. As then used, the instrument was primarily a laboratory one but its usefulness in that problem was so well demonstrated that it was deemed advisable to put the instrument into a commercial portable form.

Accordingly two preliminary models were designed and built. One of these was successfully used by two seniors in Electrical Engineering at Mass. Institute of Technology, to measure the resistances of some condensers and inductance coils at high frequencies. This work was part of a thesis problem and to the writer's knowledge has never been published.

The other model was submitted to representatives of the Weston Electrical Instrument Co. for their consideration. Following some preliminary measurements, this company undertook to change certain details in the design of the preliminary model to meet their own standards and manufacturing methods.

Largely through the efforts of Mr. Caxton Brown, and Mr. W. N. Goodwin, Jr., the development of the present model has been accomplished.

Principle of Operation

In principle the voltmeter falls in a class of instruments commonly known as thermo-voltmeters. In their usual form these instruments have been on the market for years and therefore will not be described. As ordinarily made these voltmeters may be used at all frequencies up to about two or three thousand cycles.

In the new voltmeter this upper limit in frequency has been increased to approximately one million cycles. This material increase has been accomplished by means of special shields within the meter case and a special disposition of the component parts of the meter.

How the improvement was brought about will be discussed in some detail.

Theory of the New Features

Probably the theory of the new features may be presented best by first showing why the ordinary thermo-voltmeter fails at frequencies above three thousand cycles and then by taking the reader through the same steps that were taken by the writer in his development of the meter to the final form which overcame the various difficulties encountered.

The following analysis therefore will be confined to the specific circuit in which the voltmeter was first developed and used.

That circuit is shown in Fig. 1. An ordinary thermo-voltmeter is shown connected to measure the potential drop across the resistance $A\,B$. The thermocouple is shown external of the meter case but the analysis is essentially the same as if it were enclosed. In such a circuit at high frequencies it has been found that not only does the voltmeter fail to register the true drop across $A\,B$ but it will actually give a large reading with no e. m. f. across its terminals, that is, with the resistance $A\,B$ short-circuited and again with either one of the voltmeter leads disconnected. In each case the reading was observed to increase as the meter was moved nearer the side of the circuit marked L.

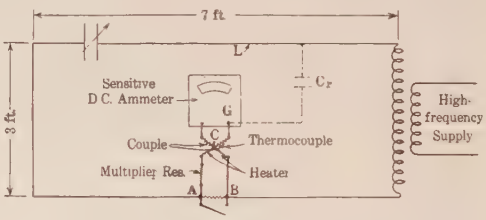

FIG. 1

Although this phenomenon appears mysterious at first sight, it is readily explained. It is due to extraneous or stray displacement currents. The principle one is that to the side of the circuit marked L because a greater difference of potential exists between that side of the circuit and the meter than between any other part of the circuit and the meter. For the present this is the only displacement current that will be considered.

Let us now trace out the path of this stray current. If $A\,B$ is short-circuited the current will divide between the paths $B\,C$ and $A\,C$. If only one lead is connected it will flow either from A to C or from B to C depending on which lead is disconnected. From C it goes to G which is that terminal to which are connected most of the metallic parts of the meter, such as the magnet, needle shield, and the like. From C it flows to L through the capacity existing between these metallic

1. *Proceedings* I. R. E., Vol. 9, page 56, 1921.

Presented at the Midwinter Convention of the A. I. E. E., Philadelphia, Pa., February 4-8, 1924.

parts and the line L. Although small this capacity is very real and cannot be neglected at high frequencies. It is represented by the fictitious condenser C_1 of equivalent capacity.

It will be seen that the stray current has, on its path, gone through the heater or at least through part of the heater. The current thus causes the meter to register and the observed phenomenon is explained. There still remains to be explained the fact that the observed reading increases as the meter is moved nearer the line L. This is due to the increase in the capacity C_1 accompanying the change in the position of the meter, which lowers the impedance of the path of the stray current and increases its value. The increased current produces a greater reading which is in accordance with the observations.

The phenomena we have just discussed begin to show at frequencies of about two or three thousand cycles and explain some of the reasons why an ordinary thermo-voltmeter begins to fail at such frequencies.

Now let us take the next step that was taken in the

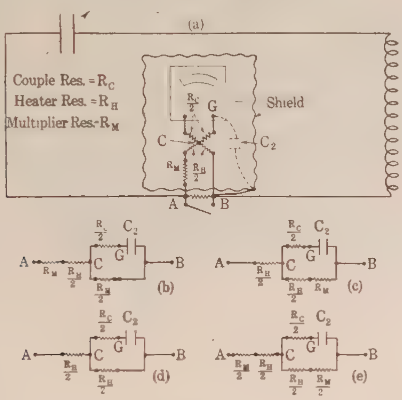

FIG. 2

development. We shall enclose the ordinary thermo-voltmeter in a metallic shield, as indicated schematically in Fig. 2a, and connect it to the point B and see what happens.

As before there will be a stray current from B to L but it does not now flow through the heater. Therefore when A B is short circuited the meter is observed to read zero as it should. However a new difficulty is encountered. It is found that in measuring the drop across A B, if the leads to the voltmeter are reversed a different reading is obtained, not a common experience with an alternating-current instrument. The difference in the two readings is observed to be greater the larger the instrument series resistance.[2]

To explain this curious phenomenon we must first observe that there is a capacity existing between G and the shield, represented by the equivalent condenser C_2. This capacity must be taken into account in an analysis of the circuit through the voltmeter. When the leads of the voltmeter have the polarity shown in Fig. 2a the circuit through the instrument may be represented by Fig. 2b. When the leads are reversed the same circuit is represented by Fig. 2c. In both figures it is assumed that the heater and couple make contact at their respective electrical centers. Actual measurements of the resistances between terminals of the thermocouple showed this assumption to be justified.

Let us now compare Figs. 2b and 2c. It is at once obvious that although the same potential be applied between the terminals A and B in each circuit, the current through the heater in each case will not be the same. This explains why the meter gives a different reading when its leads are reversed.

It will be remembered that this difference in the two readings was found to be greater the larger the instrument resistance or stating it another way, the smaller this resistance the smaller the difference. To find an explanation for this observation, let us reduce the instrument series resistance to zero and see whether the difference in readings disappears. For this to be true both circuits must reduce to an identity. They do, for they both reduce to the circuit shown in Fig. 2d. Therefore with no series resistance the meter should have its reading unchanged when its leads are reversed. This conclusion was checked experimentally.

Why do the circuits 2*b* and 2*c* reduce to an identity without a resistor and not with one? Perhaps the answer to this question will show how to employ properly a resistor. A further study of the circuits shows that without a resistor there are equal resistances on each side of the contact between the heater and the couple, while with a resistor there is more resistance on the side in which the resistor is connected. This observation at once suggests splitting the multiplier and connecting half on each lead, so as to make the resistance on each side the same. Now let us determine whether or not the circuits 2*b* and 2*c* will reduce to an identity under these conditions. They do, for they both reduce to the circuit shown in Fig. 2e.

Two difficulties have now been overcome. The single shield makes the meter read zero when it should. The divided multiplier makes the meter read the same on the reversal of its leads.

However a closer study of Fig. 2*e*, shows one more difficulty to overcome. That difficulty is, that the reading of the meter is not independent of the frequency of the applied e.m.f., due to the fact that the current through the heater obviously depends on the impedance of the capacity C_2 which is not a constant but changes with the frequency.

In solving this problem we come to the final fundamental step in the development of the meter to its present form. That step consists in splitting the shield, as we did the multiplier, into two equal parts. One is connected to one terminal of the voltmeter; the other, to the other terminal, as is shown in Fig. 3a.

An analysis of the circuit through the instrument shows that it may be represented by Fig. 3b.

An inspection of this circuit shows its striking resemblance to an a-c. Wheatstone bridge. It is

2. This series resistance corresponds to that marked "multiplier" in the drawings.

obviously balanced when C_3 equals C_4 and when the two resistances are equal to each other. That is, there is no alternating current flowing through $\frac{Rc}{2}$. When so balanced, the current through the heater resistance

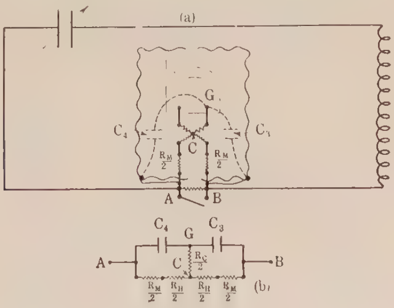

Fig. 3

depends only on the potential difference between A and B and not on the frequency, provided of course that the resistances have negligible inductance or distributed capacity.

In practice C_3 is made equal to C_4 by a symmetrical

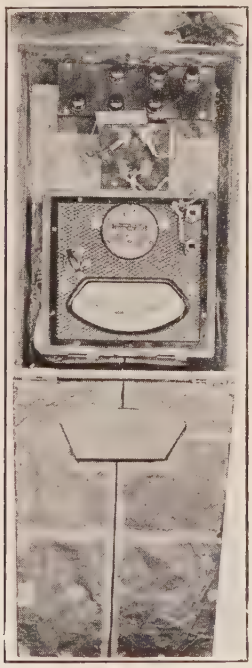

Fig. 4

placing of the meter with respect to the two halves of the shield, while the resistances are balanced by adjustment.

In this form the meter has met effectively the various requirements imposed on a high-frequency voltmeter.

The original laboratory form of the voltmeter is shown in Fig. 4.

Fig. 5 shows one of the two preliminary models in which the shielding, thermocouple, and multiplier resistance are all incorporated within the meter case.

Voltage Range

The Weston model is at present made in various voltage ranges from 1 to 20 inclusive. In these ranges the meter can be employed at all frequencies up to and including one million cycles with an error of less than 1 per cent of full scale value. Instruments of higher ranges can be built, of course, but it is doubtful whether they can be employed at so high a frequency with equal accuracy, on account of certain factors. For example, one of these factors is the distributed capacity of the multiplier resistance, which becomes more important the higher the voltage or the frequency.

Current Taken by the Voltmeter

On referring again to Fig. 3b it will be seen that the voltmeter draws two distinct currents; one through the resistances and in phase with the voltage; the other through the capacities C_3 and C_4 and 90 degrees out of phase with and leading the voltage. The first current is practically the same for all voltage ranges since the instrument resistance is proportionately greater the higher the range. The second current however is not

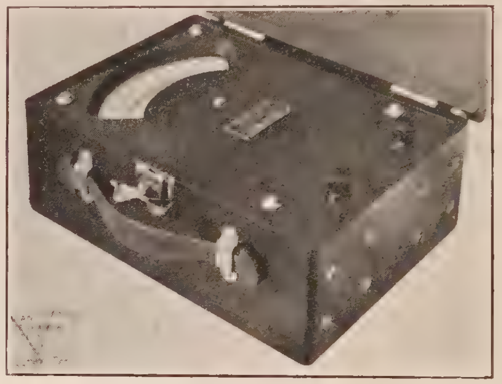

Fig. 5

the same for all voltage ranges. It increases with the applied voltage and also with the frequency of that voltage. This second current is small however and at the lower frequencies can be neglected entirely. At frequencies approaching the upper limit and particularly at the higher voltages this second current becomes appreciable and may equal or even exceed in magnitude the first current. That first current is only about two milliamperes so in any case the total current drawn by the voltmeter over its useful range is not excessive.

Precautions in the Use of the Meter

In addition to the usual well known precautions necessary in high frequency measurements, it is recommended that the voltmeter be kept well away from other parts of the circuit in which it is employed, in particular those parts which are at a widely different potential from the points to which the voltmeter is connected.

Also it is recommended that in general the meter be as symmetrically placed with respect to the various parts of the circuit in which it is employed as is feasible.

However, very good results have been obtained without taking any more than the usual care required in such measurements.

Discussion at Pacific Coast Convention

TEST RESULTS ON THE PERFORMANCE OF SUSPENSION INSULATORS[1] (BENHAM)

DEL MONTE, CAL., OCTOBER 3, 1923.

J. A. Koontz: I think there is one point that Mr. Benham has mentioned which should be emphasized, *viz.*, that if the loading on the dead end insulator is kept within reason, there is no greater depreciation on the dead end insulator than on insulators in suspension. A great many engineers feel that insulators at the dead end points are quite a hazard. In fact on the lines in question all the early type insulators used at the dead end positions had to be removed, but when they were replaced by later designed units, the trouble ceased, as shown by the curves, and from tests, we find no more failure in the dead end position than when the insulators are used in suspension. With this in view, we feel that from a depreciation standpoint, we do not have to worry about the dead end insulators, so long as the mechanical loads are not excessive.

J. E. Woodbridge: I might speak of the progress of the insulation art. So far as the suspension insulator is concerned, it has been practically developed within the last ten years. I say ten years because the difficulties with suspension insulators were first noted about ten years ago. They had then been used about five years, but nobody dreamed that they had qualities differing from those of the pin type. About the year 1913 suspension insulators began to deteriorate very rapidly; there were burnouts, punctures and flashovers, and we went out on the lines with meggers and discovered that the insulators were practically all to the bad, that they were depreciating at a high rate and that total replacement would be required within a few years. Of course, that developed a new problem and we were up in the air for some time. Some blamed the porcelain, some the metal parts, and some the cement—everybody had a different idea and each engineer proposed a different cure for the other man's diagnosis, but the whole problem is now crystallizing, as shown in this paper, to a definite knowledge of what the troubles are.

ECONOMIC CONSIDERATIONS OF POWER FACTOR CONTROL OF LONG HIGH-VOLTAGE LINES[2]

(JOSLIN), DEL MONTE, CAL., OCTOBER 4, 1923

F. G. Baum: Our vision of the future transmission system of the United States is a 220,000 volt system, at least for most of the country, and for most of the time that we will be here.

In the states east of the Mississippi River, the average transmission line distance will be around 250 or 300 miles. That is not a long transmission. In our Western country, however, we are already up to that distance, both in the north end and the south end of the state. In not very many years the southern part of the state will probably have to go over to the Colorado for its power, which means a 500-mile transmission, and the northern part of the state will have to go up to the Columbia Basin, which means again approximately a 500-mile transmission.

If we consider a circuit of 500 miles and apply voltage at one end, as shown in the paper by Mr. Peek a year ago, approximately 110-kv. at one end of the line will give you approximately 220-kv. at the other. Of course, you cannot have such a line and have it safe. So, we must have some way of holding the voltage down or stabilizing the line.

If we have the charging current at one end of the line and the capacity current is traveling 500 miles, then in that capacity current travel of 500 miles it passes over 500 miles of reactance and that is what raises the voltage of the lines.

Let us look at what are the natural characteristics of a 220,000-volt line. Let us say we have a 600,000 circular mil. copper line of any length and let us apply a load on one end of the line. I don't care whether the line is 500 miles long or 1000 miles long. Let us take the load at unity power factor and see what the characteristics are. Now increase that load gradually and take a voltage measurement along the line, when you reach a load of 120,000-kw. at 220,000 volts, you will have what we call a constant potential and a constant power factor transmission line. That is, all points of that transmission line will be at the same potential and at unity power factor. That is, there is a load for that line that when it approximates at 120,000 kw. for a 220-kv. line which makes that line a constant potential line; that I call the natural capacity of that transmission line. Of course, we can not hold the load at 120,000 kw. at all times. Suppose we trip out the switches at the end of that transmission line, then the voltage is approximately double due to the rise in voltage caused by the charging current; it would be worse than that because the charging current itself will come back to your generators and increase the excitation, and the voltage limit is unstable. We cannot have such a transmission line for satisfactory operation. In order to vary the load on that transmission line (let us again say it is 500 miles long), we locate synchronous condensers at the end and at one or two other points, depending on the location of the large loads in the large cities, etc. We may then vary the lagging or leading kv. of those condensers. Say we want a smaller load than 120,000 kv-a.; we change the condition by drawing some lagging current on those condensers and we may go entirely down to zero load, providing we make the charge kv-a. of a given section of the line come from the condensers connected to that section. That is, the charging kv-a. of the line is circulated merely through the condenser and does not travel through the entire transmission line. (I believe Prof. Ryan also showed that in a new way at that special meeting last year). When you want a higher load than 120,000 kv-a. over that line you raise the supply leading kv-a. or take it from the line wherever, or whichever way you want, and you get an economical capacity around 120,000 to 160,000 kw. and an overloading capacity of around 200,000 kv-a.

What would be the advantage of such a system? The generators would all be standard and would be uniform. That is, the excitation, in place of varying from, say, 100 amperes up to 300 amperes from no load to full load for 80% power factor, would vary from 100 to 200 amperes for unity power factor. The generator designers would have an easier job and some of the men I have talked to hope to see that day in order to relieve them of the trouble of designing from 80 to 100% power factor. Also, the transformers along such a line would be all of one voltage and standard and there would be no necessity for voltage taps. In operating such a system with those condensers tied to it, there would be a stabilizing effect produced by the condensers. The transformers would help to stabilize the line. But, a rising voltage without the condensers on the transmission line, tends to produce a further rising voltage and, therefore, produce instability; whereas with the condensers, the condensers react, and have a tendency to lower the voltage and to cause the line to operate just in the opposite way, giving you a stabilized transmission system. And, it is such a transmission system as I have in mind to cover the country.

Mr. Joslin has shown in his paper the economic value of the condensers for 220 kw. transmission.

This is also shown on pages 15 and 18 of the Atlas of U. S. A. Electric Power Industry. The addition of the condensers does not materially increase the cost of the transmission, but the addition gives a safe line, and a line that may be extended as far as economy dictates. With the condensers we also obtain increased capacity so that the cost per kw. for transmission is reduced.

1. A. I. E. E. JOURNAL, 1923, Vol. XLII, December, p. 1257.
2. A. I. E. E. JOURNAL, Vol. XLII, 1923, December, p. 1248.

I especially urge electrical engineers to study the characteristics of the constant potential 220 kv. transmission with condensers for voltage control. I think they will find that this gives a system of transmission commensurate with the needs of the industry at this time.

J. P. Jollyman: It is fortunate that the engineer, taking advantage of the information that Mr. Joslin has presented, can say in some cases, "Spending a half-million dollars for synchronous condensers will do more good than spending it for additional transmission circuits."

I think the economic phase of the problem has not been emphasized enough in the past.

PERFORMANCE OF AUTO TRANSFORMERS WITH TERTIARIES UNDER SHORT-CIRCUIT CONDITIONS[1]

(Mini, Moore and Wilkins), Del Monte, Cal., October 4, 1923

L. F. Blume: The subject of the paper by Messrs. Mini, Moore and Wilkins involves many interesting problems because the transformer connection to which the authors mostly refer is a mongrel which has inherited its peculiarities from three distinct sources. For, in this one transformer connection are combined the various aspects of (a) an auto transformer, (b), the *Y* connection, and (c) the 3-winding transformer. I will point out briefly for purposes of emphasis, a few of the salient characteristics of only one of them, namely, the 3-winding transformer.

Wherever transformation of power is desired between three circuits, the practise of using three windings of different voltages is growing on account of the resulting economy, not only in first cost, but also in operation. By using one transformer bank rather than two, double transformation of power is avoided and the total amount of transformer kv-a. for a given service is correspondingly reduced. A particularly interesting and important illustration is in high-voltage transmission where synchronous condensers are used for power factor control, in which case the synchronous condenser sometimes is neutralizing the lagging reactive current of the low-voltage system and at other times it is neutralizing the leading charging current of the high-voltage line. The joining together in one bank, of the transmission line, the low-voltage circuit and synchronous condenser for the purpose of transforming directly from any one circuit to another by one transformation is the unique function of the three-winding transformer.

In addition to this, however, it is also being frequently used where the *Y-Y* connection is primarily desired, the third winding being added merely to correct the inherent weakness of the *Y-Y* connection. These inherent weaknesses resulting sometimes in abnormal voltages either in the connection or in the line, or sometimes in interference with parallel telephone lines and also in various operating difficulties, may be grouped under the rather broad generalization of neutral instability. This use of the tertiary delta in itself, is good evidence of the superiority of the *Y*-delta connection, for by the addition of the delta the stable characteristics of the *Y*-delta connection is secured. It is desirable to point out in this connection that if the tertiary winding is not needed for loading purposes the *Y*-delta connection is simpler and cheaper, and therefore, the only legitimate reason for adding the third winding is found in those cases where the system conditions are such that a *Y* connection for both the primary and secondary windings is essential.

Thus it is seen that the 3-winding transformer is being employed for two distinct reasons, the one being based on economy both in first cost and operation; and the other being for the purpose of securing specific improvements in operating characteristics. The one purpose may be called the economical use, and the other, the non-economical use of the 3-winding transformer.

1. A. I. E. E. Journal, Vol. XLII, 1923, December, p. 1243.

However, whatever may be the reason for the use of the three windings, the majority of them are connected in *Y-Y* delta, with the delta tertiary having a capacity considerably less than the rating of the main windings. In these cases the size of the tertiary winding may not be determined by the load which it is to deliver, but rather by other characteristics such as the short-circuit current. For example, a short circuit from line to neutral on either of the high or low-voltage circuits results in a short-circuit current circulating in the delta limited only by the internal reactance of the tertiary winding. In this case the controlling factors in design as pointed out by the authors, are the amount and duration of the short-circuit current.

It may be well to add that when a tertiary winding is to be designed for a given short circuit and for a given length of time, these other terms, kv-a. rating and reactance become superfluous and are arbitrary.

Where the tertiary windings constitute an important protective link in a system, it is highly desirable that they be sufficiently liberally designed so as to possess an ample margin of safety from the point of view of the mechanical forces and the thermal effects resulting from short-circuit currents. The certainty that the over loading of tertiary windings will be much more frequent by short circuits and also of longer duration than in ordinary transformer windings is an additional reason for a conservative policy. Moreover in most instances a larger tertiary costs comparatively little more than a small tertiary. For example, comparing a 50 per cent with a 25 per cent capacity tertiary winding, the former involves only 5 or 6 per cent increase in transformer cost.

To determine the short-circuit and regulation performance of a three-winding transformer it is essential to have a clear conception of the manner in which the reactance between the windings affects the current division, regulation and short-circuit currents. The determination of these characteristics may prove to be very perplexing and unnecessarily complicated unless the fundamental relations are clearly understood. These relations, however, are fortunately quite simple.

In a two-winding transformer the internal impedance is usually expressed in terms of one value. The leakage reactance between primary and secondary, and the resistances of the two windings are lumped into one and thus one value of impedance is sufficient to express the voltage consumed internally by the transformer. From time to time academic discussions arise concerning how much of the reactance belongs to the primary and how much to the secondary but no practical use is served in attempting to make this distinction and no matter how the reactance is assumed to be divided between high-voltage and low-voltage windings, the performance of the transformer remains unchanged. Therefore, it is common practise to use only one value to express the impedance of a two-winding transformer. The reason that this may be done is because the high and low-voltage currents are equivalent and in phase.

On the other hand in 3-winding transformers the current flowing in one winding is not necessarily equivalent to, nor in phase with, a current in one of the other windings, and for that reason resistances and reactances cannot be so simply expressed. It is convenient, and in fact necessary, to consider that every winding possesses a reactance belonging to itself just as distinctly as its resistance, and that they are connected together in the equivalent circuit in *Y*. Having segregated in this manner the impedances into a primary, a secondary and a tertiary value, regulation drop can be calculated for each one separately by using the ordinary formula for regulation, and also by means of the simplest algebra, current division for any condition of loading or of short-circuit condition can be readily determined.

Thus there are two new problems introduced by the 3-winding transformer. First, the determination of the size of the tertiary winding may not be obtained in the ordinary manner but by one or more of the unique functions which it is called upon to

perform. Second, the three windings are so related to each other that impedance and regulation cannot be so simply expressed as in ordinary transformers, although by means of a simple equivalent circuit, equivalent impedance values can be determined for each winding and these values used in the ordinary formulas to obtain regulation or current division for any given condition.

A. Boyajian: There is an implied recommendation in the paper by Messrs. Mini, Moore and Wilkins that tertiary windings should have larger capacity or larger margin of safety; a suggestion which deserves serious consideration, especially in view of the relatively small cost that it involves.

Relative Cost of Tertiary Windings: In three-winding transformers a larger tertiary costs only a trifle more than a small tertiary. For instance, a transformer with a 50 per cent tertiary winding has a total kv. rating which is only about ten per cent larger and a cost which is only about five or six per cent greater than a similar transformer which has only a 25 per cent capacity tertiary. That is, the capacity of the tertiary winding can be doubled with only a five or six per cent increase in the cost of the transformer. Although it seems to be common practise to rate tertiary windings in the neighborhood of 25 per cent (excepting those which have to carry large loads normally), I happen to know that in a number of cases a manufacturer furnished tertiary windings with capacities much in excess of the capacity specified in the contract, simply because the additional expense involved was very small while the greater security to the transformer resulting therefrom was very large.

Tertiary windings cut a somewhat larger figure in the case of auto transformers than in transformers on account of the fact that the economy in the primary and secondary circuits accomplished by their auto-transformer connection does not apply to the independent tertiary winding. For instance, in a two-to-one auto-transformer, the cost of fifty per cent capacity tertiary may be about 10 per cent more than that of a 25 per cent capacity tertiary. But even in this case the extra cost is small, the capacity of the tertiary being doubled with only about 10 per cent increase in cost.

In as much as a tertiary winding is an important protective link in a system, its capacity should be specified liberally, though not wastefully, and this naturally raises the question as to what is the proper capacity for tertiary windings.

Factors Controlling Tertiary Capacity: The authors have properly recognized that the tertiary capacity and the tertiary reactance are interdependent and that when one is given the other is fixed thereby. The reactance in this case can of course only mean the net equivalent reactance as effective in the limitation of the short-circuit current. In other words, the capacity of the tertiary winding is determined by its short-circuit load. I wish to point out, however, that the *duration* of the short-circuit load is just as important a factor as the *magnitude* of the short-circuit load in the determination of the necessary tertiary capacity. This point probably can be best brought out by a comparison as follows:

Transformers are as a rule guaranteed for a two-second duration of short circuit. If we arbitrarily assume 5 per cent reactance as an average conservative lower limit of reactance for convenience in this illustration, it means that the conductor can carry twenty times its rated current for two seconds without exceeding a certain permissible temperature rise. From the standpoint of temperature rise based on heat storage, we have the following approximate equivalents:

20	times	normal	current	for	2	seconds.
= 14	"	"	"	"	4	"
= 11.5	"	"	"	"	6	"
= 10	"	"	"	"	8	"
= 7.8	"	"	"	"	10	"

That is, a normal transformer winding will carry 7.8 times (call it 8 times) normal rated current for 10 seconds, on a conservative basis.

If the duration is assumed fixed, the capacity of the tertiary varies directly as the current. Based on the 10 seconds time for tertiary relay operation assumed by the authors we have the following table of values:

Duration of short-circuit assumed 10 seconds.

Short-Circuit Current	Tertiary Capacity in Per cent of Primary
8 times normal primary	100
6 "	75%
5 "	62%
4 "	50%
3 "	37%

This table shows that if a tertiary winding which is to carry four times rated primary current for 10 seconds is to have the same margin of safety in temperature rise as a 5 per cent reactance transformer designed to operate at normal conservative densities, it must have about 50 per cent of the capacity of the primary. Otherwise, it will have a smaller margin of safety.

It may also be interesting to note a table of tertiary capacities for various currents for a shorter duration, say 6 seconds.

Duration of short circuit 6 seconds.

Tertiary Short-Circuit Load	Tertiary Capacity in Per cent of Primary
11.5 × normal primary	100%
10 "	87%
8 "	70%
6 "	52%
4 "	35%
3 "	26%

It is not the object of this discussion to recommend any particular tertiary capacity nor the magnitude or duration of the short-circuit currents, but to indicate how the relative merit of tertiary capacity can be estimated in terms of customary values applying to the major windings and to emphasize the wisdom of specifying tertiary capacities ungrudgingly in view of the very small additional cost involved.

A further circumstance that makes a conservative policy towards tertiary windings desirable is the certainty that short-circuits which will load-up tertiary windings to their full capacity will be much more frequent than short-circuits which will load up the major windings to their full capacity. In other words, line-to-ground short-circuits are bound to be much more frequent than line-to-line short-circuits, and, hence, tertiary windings will have their ordeal oftener than the major windings.

Relation of Reactance to Short-Circuit Currents and Tertiary Capacity. Reactance in connection with tertiary windings usually means the reactance between the tertiary and the primary circuits. This reactance, however, does not directly and completely determine the short-circuit currents of the tertiary winding for all the various possible system connections and location of short-circuit. These are so varied that time would not permit their discussion now, but in any practical case, it is necessary to consider the various possible conditions, especially two of them, *viz.*, (a), the condition for the sake of which the tertiary winding is to be provided, together with, (b), the condition which imposes the severest duty on the tertiary winding. For instance, in a system grounded at a number of points for purposes of selective relay operation, a short-circuit across the terminals of the tertiary winding is likely to be a much more severe load to it than a line to ground short-circuit on the primary or secondary lines. In such an instance, if it is not absolutely necessary that the tertiary should furnish a load normally, it would be better policy not to bring out tertiary leads and thus avoid the extra risk that would otherwise be incurred.

Test Data: The authors present a number of interesting test data in curves and vector diagrams. All of these could have been predicted accurately by calculation, and the following comments may be interesting and helpful in their interpretation.

1. Figs. 1 and 2 of the authors are the experimental verification of two theorems or principles, *viz.*:

(a) Y-delta (or delta-Y) connected transformers operate equally well on unsymmetrical as well as symmetrical line voltages, that is, lack of balance or symmetry in the line voltages does not produce any circulating current in the delta.

(b) The leg voltages of a Y-connected bank of three similar transformers are equal to two-thirds of the corresponding median of the triangle of line voltages. On the side of the vertical leg the median of the line voltages is 244/2, that is, 122 volts, and $^2/_3$ of this, that is, 81 volts, should appear across that leg. The observed voltage is 80 volts, which may be considered as a complete commercial check. The fact that the observed voltage on the delta side on the corresponding leg is 4.7 volts proves by ratio that the observed voltage on the Y side must have been nearer 81 volts than 80.

2. In Fig. 3 excitation is applied only to the lower two legs (V_1, V_2). The vertical leg is short-circuited, but this short circuit does not affect the circuit in any way because the delta is open. The phenomena are capable of prediction by very elementary considerations, but presumably the authors included this in their tests for comparison with the case of Fig. 4.

3. Fig. 4 is the same as Fig. 3 except that the delta is closed. The vertical leg is disconnected from the generating system (note the break in the upper transmission line) and is short-circuited. The object of this line-break was no doubt to prevent a direct dead short circuit on the left hand bank of transformers at the generating end, because the break does not influence the phenomena of the righthand bank (the bank under test) in any way. The formula for the short-circuit current in this case is:

$$I_c = \frac{\%\ E}{3 \times \%\ I\ Z} \times \text{rated current}$$

An interesting fact about the short-circuit current of this case is that if the step-up transformers were not grounded, only the step-down bank being grounded, (in which case the upper line break would be dispensed with) the coil currents in the short-circuited step-down bank would be three times as large as the figures given above. This is a good illustration of the influence of system connection and number of neutral grounds on the short-circuit currents.

The voltages on the delta side by ratio from the primary Y side would be 14 volts. The short circuit current being only one third of that corresponding to a short-circuit on a unit as a single-phase unit, the voltage on the delta side of the short-circuited leg will be one third of the excitation, namely, one third of 14 volts, or, 4.7 volts. The measured value is 4 volts, and the small discrepancy may probably be accounted for by reading the voltmeter very low in the scale, as would be the case if the scale was of the order fo 50 volts or more. The voltages on the other legs would be 12.3 volts, the measured value being 12 volts which may be considered a sufficiently close check.

4. Fig. 5 is the verification of the simple statement that if one leg of a Y-Y bank is short-circuited, the other two legs take up the full line voltage in open-delta. The corner of the tertiary delta winding is open, at which point 41 volts, which is 1.73 times the voltage of the excited legs, is observed, being the vector sum of the two excited legs with a 60 deg. angle, as the authors have indicated in the vector diagram. When the open corner of the tertiary delta is closed, this voltage is short-circuited and we have the case shown in Fig. 6.

5. The calculation of the currents in Fig. 6 would require a knowledge of the impedance between the tertiary and the secondary. This is not given, but in as much as the currents are given, it is possible to reason back from them to the value of this reactance which figures out to be about 13.5 per cent and which we may apply to the solution of other cases, as for instance the case of Fig. 7.

6. In Fig. 7 short-circuit current could be furnished with the upper transmission line on open circuit, that is, the vertical leg not taking any part whatever. Short-circuit current could also be furnished with the lower two transmission lines on open circuit, that is, the lower two legs not taking any part whatever. This means that we have in effect two sources in parallel furnishing current to the short circuit. What the actual short-circuit current will be and how it will distribute itself in the network may be calculated as follows:

Let us call the upper vertical leg, on primary side, circuit A; the lower two legs together, B; and the line-to-neutral circuit on the secondary side, C.

When the upper leg circuit (A) alone is excited, lower legs (circuit B) being disconnected, the impedance effective from A to C is

$$\%\ I\ X_{ac} = \%\ I\ X_{ps} = 5.7 \text{ per cent}$$

When the upper leg (circuit A) is disconnected, and the lower legs (circuit B) alone furnishes the load in C, the effective impedance is

$$\%\ I\ X_{bc} = 2 \times \%\ I\ X_{pt} + \%\ I\ X_{st} = 53.5 \text{ per cent}$$

Evidently, the impedance from A to C being about one-tenth of that from B to C, we can say as a first approximation that the former will furnish 10 times as much kv-a. into the short circuit as the latter. Since the voltage of the former is twice that of the latter, its current will be five times as much to make its kv-a. ten times as much. Considering the test data we find that the current in circuit A (vertical leg) is 3.78 amperes, and that in circuit B (lower two legs) is 8 amperes total, the ratio being about five to one. The effective impedance of the two circuits A and B in parallel for the circuit C will be approximately

$$\%\ I\ Z_c = \frac{1}{1/5.7 + 1/53.5} = 5.2 \text{ per cent}$$

$$I_c = \frac{\%\ \text{Excitation}}{\%\ I\ Z_c} \times \text{Rated current}$$

$$= 0.6/5.2 \times 225 = 26 \text{ amperes.}$$

The observed current is 24 amperes, about 8 per cent lower, which may perhaps be accounted for partly by the impedances introduced into the circuit by the meters, leads and grounds, and partly by the approximateness of the data on which the calculation is based.

The exact calculation of problems like this involves some methods into a discussion of which we cannot enter now but which will be found described in a paper entitled "Theory of Three-circuit Transformers" to be published in a forthcoming issue of the JOURNAL of the Institute.

8. Of the tests with auto-transformers, Fig. 10 is of particular interest illustrating the reason for and widsom of the two simple general maxims for the operation of auto transformers, *viz.*: "If the system is grounded, ground the neutral of the auto-transformer; if the system is isolated, isolate the neutral of the auto-transformer." In Fig. 10, the delta is open, so that the unit is acting as a straight Y auto-transformer, and it is found that if the system is grounded and the auto-transformer is isolated, a line ground on the secondary over-excites that leg in the ratio $E_1/(E_1 - E_2)$ and shifts the neutral. In this case, the low voltage being 50 per cent of the high voltage, this ratio was 2. If the low voltage had been 90 per cent of the high voltage, this ratio would be 10, that is, the leg whose line is grounded would be overexcited 10 times. This would of course overexcite the other legs also. If the primary is the low-voltage side, a high-voltage line ground not only overexcites but also reverses the voltage of the corresponding leg.

TRANSFORMERS FOR HIGH-VOLTAGE SYSTEMS[1]

(Copley), Del Monte, Cal., October 4, 1923.

E. A. Smith: It would be quite interesting if Mr. Copley would give some more information on these 220,000-volt circuit breakers, such as the necessary data on the rupturing capacity, size of tanks, amount of oil, the grade and the insulating factors, what sort of contacts used and the depth of contacts under the oil.

Also the general tests and curves covering all the characteristics of flashover and safe operating limits.

R. W. Sorensen: Mr. Copley's paper sums up nicely the present-day accomplishments toward the consummation of the 220,000-volt, 1100-mile California bus-bar system as proposed at the 1919 Pacific Coast Convention held in Los Angeles. At that time I hardly thought the plan presented would in any way be realized in less than a decade.

In paragraph two, Mr. Copley speaks of graded insulation being used. Descriptive articles I have read and a rather casual inspection of some of these transformers I have seen out of the tank did not indicate to me a truly graded insulation. To my way of thinking, the term "graded insulation" means a tapering insulation. I am under the impression that, with the exception of the end turn insulation, the insulation between turns is uniform throughout the winding. Also I did not find grading between high-tension windings and core legs. What I have understood is that the large insulation barriers used in the more familiar types of construction, between coils and yokes have been left out, a condition made possible by a plan of construction which permits a single high-voltage lead to be brought out from the center of the coil stacks. This form of construction is not original with the 220,000-volt transformers, as it was first made known by the W. J. Wooldridge patents, so old they have expired, and afterwards used in the Fortescue plans for stress distribution, published about ten years ago. In practise, it has been tried out on many voltages for several years. It is not a scheme necessary for engineering reasons, but is largely one of economy, determined not only by the voltage, but also the rating of the apparatus. I think it would be a mistake to create the impression that transformers for this voltage can be built only with one insulated lead and a solidly grounded winding.

This brings us to a point in paragraph three. I rather doubt the advisability of saying engineers are universally of the opinion that 220,000-volt systems should be provided with solidly grounded neutrals only. As such a system grows it may be necessary to use Peterson coils, or a resistance of some type in the neutral of 220,000-volt systems and also for systems for other voltages, even though we have by long practise become accustomed to the use of solidly grounded neutrals on the Pacific Coast.

It seems to me ample provision for giving single terminal transformers a voltage test made in Rule 6362 of the A. I. E. E. Standards which reads, "Under certain conditions it is permissible to test transformers by inducing the required voltage in their windings in place of suing a separate transformer. By 'required voltage' is meant a voltage such that the line end of the winding shall receive a test to ground equal to that required by the general rules."

Further, the Standardization Rules call for a specific test for three-phase work of two times line voltage, because many years of practise show this to be desirable. This of course gives a ratio of transformer test voltage to transformer working voltage of 3.46 in a Y connection and of 2.00 for a delta connection. Also, Rule 6321 (*e*) specifically states that single-phase systems permanently grounded used for more than 300 volts shall be tested at 2.73 times circuit voltage plus 100 volts. If this difference is unwarranted, the matter should be corrected by a change in the Standardization Rules and not by an avoidance thereof.

The economy and also the difficulties encountered in the use of auto-transformers are well known. Therefore, to avoid most of these difficulties auto-transformers, when Y-Y as they usually are, are provided with tertiary windings. The capacity of the tertiary winding is determined by its ability to take care of short circuits. The tertiary winding by providing a path for the third harmonic component of the exciting current, stabilizes the neutral, and should a ground occur on the system it provides a path through which current can flow until a balance is obtained, but if there were no tertiary winding there would be no current flow, as indicated in the seventh line from the bottom of column one of the 2nd page of Mr. Copley's paper. For my part I can see no particular reason to assume the tertiary more immune from trouble when left idle than when used to supply power, as power load, or to a synchronous condenser, providing proper precautions are taken against faulty connections and overload. Of course, if there is a large leakage reactance factor between tertiary and secondary winding of the transformer, the secondary voltage could not be expected to stay constant if the regulator were set to regulate on the teritary or the primary, but I see no reason why a condenser can not be supplied with power by the tertiary and yet be made to regulate either the secondary or primary voltage as desired.

A. W. Copley: Professor Sorensen is correct in his statement that the insulation between turns in a transformer with "graded insulation" is uniform throughout the body of the winding except for the end turn padding. The grading is, however, accomplished in the insulation from coils to ground as it is the potential from coils to iron that varies from zero at the ground end to a maximum at the line end of the winding. In shell type construction the grading is done in the group insulation.

The fundamental reason for grading is economic and its justification is the fact that with one end of the winding solidly grounded there is no necessity for taking up space by also insulating this end for full voltage. For the same reason there is no necessity for a high-voltage bushing on the ground end of the winding. The only systems now operating at 220 kv. use the solidly grounded neutral and I have yet to hear engineers seriously propose to operate at such voltages with neutrals either free or grounded through resistance or reactance.

As to the test voltage value for transformers having graded insulation, I explained in my paper the reason for the acceptance of a value of 2.73 times the voltage from line to neutral. Although this is a lower value than is called for by a strict interpretation of the Institute Standards, I believe it is justified and consistent with the values used on transformers with straight insulation which might be used on free neutral systems. The present standards take no cognizance of the graded insulation transformer in the test values given.

The desirability of taking load from transformer tertiaries in addition to the condenser current is largely a question of voltage regulation. The condenser may be used to regulate the voltage on any one winding but not on two simultaneously. In most instances it is desired to regulate the secondary voltage and in these cases the tertiary voltage will generally vary over so wide a range as to make it unsatisfactory for supplying load.

GROUP OPERATION OF SYSTEMS HAVING DIFFERENT FREQUENCIES[1]

(Stauffacher and Briggs), Del Monte, Cal., Ocotober 5, 1924

L. M. Klauber: There are two points upon which I should like to comment from the standpoint of a smaller company engaged in interconnection with a larger.

Mr. Stauffacher has told you of the smoothness of operation of frequency changes used in interconnection. On the contrary operation is not always so simple for the smaller company.

One point I might mention is that of governing. Steam turbines appear to be equipped with governors which are inherently more sensitive than those on the hydraulic machines. There-

1. A. I. E. E. Journal, Vol. XLII, 1923, December, p. 1259.

fore, a smaller system with steam turbines tied to a large system, principally hydro, through frequency changers tends to either feed into the large system or take from it a violently fluctuating block of power. For this reason it is necessary when our system is tied to that of the Southern California Edison Co., to change the degree of sensitiveness of the governors on our steam turbines. This has proved quite a problem. A method was finally devised whereby this might be done with entire satisfaction in a practical way, but unfortunately it is a method that is frowned upon by the manufacturers of the turbines. Yet, so far they have been unable to offer any other practicable solution. Our method is to place on one of the operating rods of the governor a device which we call a "load steadier" which works by friction on the governor shaft. It works, as I say, with entire satisfaction and it so arranged that the load on the turbine may be varied from the switchboard in the usual way. It may be instantly released if desired.

Recently, we have tried a second means of governing. We fix the turbine load for a certain specific amount by partially closing the hand throttle so it cannot carry more than that amount with all the governor valves wide open. The result is a decreased efficiency, approximately 2 per cent below the other method of governing, but it is thought by some to be safer. We operated for approximately a month, alternating between the two methods in order to determine the relative efficiency of each. This matter of control of governor sensitiveness is a point to which the manufacturers should give some attention.

Another matter is that of load control, which, again is somewhat difficult. Without frequent telephone communication it is difficult to carry the load at a maximum and yet within the capacity of the frequency changer. It, therefore, becomes necessary for the operators to do considerable guessing, in which they ultimately become quite expert, for if load is being taken from the line between the generating station and the frequency changing station, it is obvious they must make calculations of the load which is being taken off along the way, so that the ultimate load which reaches the frequency changer is not beyond the capacity of the machine.

P. M. Downing: My experience has been that where you attempt to operate turbines in parallel with a large hydroelectric system you must of necessity make your governors more sluggish; otherwise, your steam turbine will one moment have no load and the next moment it will be overloaded. That is not due entirely to changes of frequency on the larger system, but due to the inherent differences in governing between a steam turbine and a water power governor.

O. B. Coldwell: Our company has two frequencies, 33 1/3 and 60 cycles. There are frequency changers in operation tying the two systems together. We have been for several years past doing away with the 33-cycle apparatus. To a considerable extent this has been accomplished by remodeling 33-cycle machinery for 60-cycle operation.

WASHINGTON ADOPTS CODE

The State of Washington has just adopted Industrial Lighting regulations as a part of its Safety Code making the tenth state in which such regulations are in effect. It is estimated that the territory now covered with the industrial lighting regulations, based upon the American Engineering Standards, sponsored by the Illuminating Engineering Society, represent approximately 40 per cent of the country's population. The states having such codes are Pennsylvania, New Jersey, New York, Wisconsin, Oregon, California, Ohio, Oklahoma, Massachusetts and Washington.

1. A. I. E. E. JOURNAL, Vol. XLII, 1924, November, p. 1129.

THE RELATION OF ILLUMINATING ENGINEERING TO THE CENTRAL STATION

Complex as the relations of our great public utilities to all phases of modern life seem to the observer, the fundamental basis of these relations is, as in all other industry, service. From the simplest forms of service a continually increasing variety has been developed to meet the demands of mankind. These demands have grown in natural sequence along the lines of safety, utility, and beauty, although in recent years demands for amusement and diversion have grown to enormous proportions.

To meet all these demands service must flow in to the supplier along the lines of capital, plant, raw materials, special skill, labor, etc. From the supplier must flow out the product, finished and ready for use or translatable to meet the demands of modern life.

Certain of our public utilities, such as the railroads and street railways supply a finished product in the form of service to meet given demands. The central station, however, supplies a product which is of no value to mankind unless translated into light, heat, or power to meet the requirements of our modern life. In fact, the entire central station industry was built upon the demand for artificial light as a complement to natural light and upon the fact that electricity could be translated into a form of artificial lighting to meet the demand.

From the very first, the central station found that in order to market its products it was necessary to sell service with the electric current in order that existing demands might be satisfactorily filled and new demands created.

In this brief statement may be found the fundamentals of the relations of illuminating engineering to the central station industry. Flowing into the supply company are the results of all the research work relative to the requirements for and possibilities of artificial illumination along the lines of safety, utility, beauty and amusement. Flowing out with the electric current—as service accompanying the sale—are the advice, assistance and supervision, which make it possible to complete the supply of these demands in a scientific and economical manner.

The accomplishments of illuminating engineering in the directions of measuring the necessities for artificial lighting and in pointing out the best way to fill these demands in all the phases of modern life are too well recognized to require an extended review.

The central station which receives all the service that illuminating engineering can give and continually supplies that service—with its product—to meet the demands of modern life, will thus be enabled to furnish, instead of raw energy, a lighting service of the highest and most satisfactory type.—C. S. Russell, in *Trans. I. E. S.*, Jan. 1924, p. 91.

Magnetic and Electrical Properties of the Ternery Alloys FE-SI-C.

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Review of the Subject.—*The variations in the magnetic properties of iron and iron-alloys, even of supposedly constant composition, have been puzzling to the users and investigators of ferro-magnetic materials ever since the introduction of such materials for electrical apparatus. The author started to investigate this problem over ten years ago at the University of Illinois, and has continued it at the Westinghouse Research Laboratory since 1916, concentrating on iron and iron-silicon alloys. While the results obtained do not eliminate 100 per cent of the difficulties, they go a long way in that direction.*

It has been found that carbon is largely responsible for the variations, because of the fact that amounts so small as previously to be regarded as traces—less than 0.01 per cent—remain dissolved in the iron in the solid state, even after slow cooling, and have a tremendous influence on the magnetic properties. Of much less effect is carbon precipitated as pearlite, free cementite and graphite, the effect being in the order named. If the effect of dissolved carbon be represented by 100, the effect of carbon as pearlite is 16.5, of carbon as Fe_3C *2.25, and of carbon as graphite nearly nil. The form assumed by carbon—aside from the carbon in solution—depends largely on the silicon content, and can best be explained by referring to Fig. 9.*

Besides carbon, it has been found that the grain size has a large and definite influence on the magnetic properties, due to the accompanying intercrystalline amorphous cement that may be regarded as an impurity similar to other intercrystalline impurities.

The detrimental effect of sulphur, phosphorous and manganese on pure iron is in the order named, while phosphorous has a beneficial effect on high silicon alloys.

The evidence obtained is to the effect that the increased reluctivity, coercive force, or hysteresis loss, due to carbon and other impurities that are precipitated combined with iron—including in this class the inter-crystalline cement—is caused by the inherent corresponding property of these precipitated impurities.

Regarding the tremendous effect of carbon in solution, it is suggested that this is due to the entering of carbon into the more or less stable equilibrium arrangement of the ferro-magnetic structure, upsetting this equilibrium arrangement.

I. Introduction

THE superiority of Si-steel over plain iron for magnetic purposes was discovered by Hadfield in 1899.[1]

The steel, containing 4 per cent silicon, was first used commercially in England in 1903[2] and immediately proved a decided success. The first patent in the United States[3] on silicon steel was granted Hadfield on December 1, 1903, but it was not until 1906 that the first transformer was built in this country using the new steel. Since that time silicon steel has been used almost exclusively for transformers, both here and abroad, with an enormous saving in energy, and it is still without a competitor, in spite of the many investigations[4] made for the purpose of discovering one. However, the 4 per cent silicon steel of today is much better, magnetically, than Hadfield's original steel, due to improvements in manufacturing processes, in raw materials and in methods of heat treatment. Roughly speaking, the hysteresis loss is only one-half and the maximum permeability is at least twice that of Hadfield's steel, but these improvements were largely accomplished prior to 1910. During the last ten years the average improvement, as far as can be gathered, has been approximately 1 per cent per year, and this improvement has been due more to minor improvements in the heat-treatment than to refinements in composition.

Resume of Previous Investigations

The effect of the ordinary impurities on the magnetic properties of iron and iron alloys has not to any great extent formed the main object of systematic scientific investigations. The most probable reason for this is that the factors influencing the magnetic properties are too numerous and were not sufficiently well known to enable the investigators to eliminate the undesirable variables. The objects have rather been to determine the magnetic properties of alloys of iron with elements that will, or may, bestow decidedly new and useful properties upon the iron, and to disregard the effect of such incidental impurities as usually occur in commercially pure iron of the best grades. Hadfield,[5] for example, used Swedish charcoal iron as the base for his investigations and prepared his alloys under commercial conditions. Burgess and Aston[6] on the other hand attempted to get away from this uncertainty and were the first to use electrolytic iron as the base for their alloys. Unfortunately, however, the prepara-

1. Barrett, Brown & Hadfield; *Sci. Trans.*, Royal Dublin Soc. VII, Ser. 2, part 4, January, 1900.

Journal Inst. Elec. Engrs., Vol. 31, 674 (1902).

2. Hadfield: History of the Metallurgy of Iron and Steel, *Proc.* Inst. Mech. Engrs., February, 8, 1915, p. 332.

Yensen: The Development of Magnetic Materials, *Elec. Journal* 18, p. 93, March, 1921.

3. U. S. Patent No. 745, 829.

4. See: TRANS. A. I. E. E. 34, p. 2455 *et seq.* Oct. 1915, *Historical Review*, Bull's 72 and 83. Eng. Exp. Stn. Univ. of Ill., Historical Reviews.

Abridgement of paper presented at the A. I. E. E. Midwinter Convention, Philadelphia, Pa., February 5, 1924. Complete copies available to members on request.

5. Barrett, Brown & Hadfield: *Sci. Trans.*, Royal Dublin Soc. VII. Ser. 2, p. 4, January, 1900.

Journal Inst. Elec. Engrs. 31, p. 674, (1902).

6. *Trans. Am. Electrochem.* Soc. XV. p. 369, (1909). *Chem. & Met. Engr.*, January, February, March, April, 1910.

tions were made under conditions (a Hoskins carbon plate furnace) that reintroduced carbon in varying amounts into their alloys and they consequently lost the advantage they had in using a pure base. When the writer started his investigations in 1912 he took advantage of the results of Burgess and Aston and prepared his alloys in a vacuum furnace in such a way that carbon was further eliminated rather than reintroduced, with the result[7] that the magnetic properties obtained, both for pure iron and for iron-silicon alloys, were far superior to those obtained by previous investigators. The results for pure iron were later confirmed by Gumlich, using Fischer electrolytic iron and vacuum treatment.[8]

In these cases, the efforts were concentrated on eliminating and on keeping away the impurities, but in spite of these efforts it was impossible to obtain consistent results and to duplicate results. Not having control over some of the most important factors, and, what was worse, not even knowing what they were, it was evidently useless to attempt to determine the effect of impurities that might produce changes far less than the changes caused by the uncontrollable impurities. Aside from the usual impurities, the question of grain size enters as an important factor affecting the magnetic properties. Ruder has found[9] in the case of silicon steel that the larger the grain size the better the magnetic properties; he also showed how the grain size could be increased, by cold deformation followed by high-temperature annealing, without, however, being able definitely to control it.

Preliminary Work

When, in 1916, the writer transferred his activities to the Research Laboratory of the Westinghouse Company and there tried to duplicate the results previously obtained at the University of Illinois, difficulties were encountered. The results for pure iron checked fairly well but not so for the iron-silicon alloys. The magnetic properties were generally very much inferior and the more so, the higher the silicon content; furthermore, the results varied depending upon the grade of silicon used, in spite of the fact that chemical analysis of the alloys revealed no consistent differences. After a great deal of experimentation on 4 per cent Fe-Si alloys, it was found that annealing under oxidizing conditions at a temperature of 950, 1100 deg. greatly improved the magnetic properties, while annealing in vacuum, hydrogen or nitrogen had no such beneficial effect. By applying this method of heat treatment to the original series of Fe-Si alloys, it was found that all of the alloys were susceptible to the treatment. Some responded very quickly (an hour or two at 1100 deg.) while others were much more resistant (requiring 8 to 10 hrs.) but in all cases, the maximum permeability reached 20,000-35,000 and the hysteresis loss 400-550 ergs per cu. cm. per cycle for $B = 10{,}000$ gauss. Furthermore, it was found that commercial 2 and 4 per cent silicon steels could be improved to nearly the same extent as the laboratory prepared alloys. Analysis of the gases given off during the annealing confirmed the suspicion that carbon was being eliminated and quantitative tests revealed some relationship between the magnetic properties and the amount of carbon eliminated. It was concluded that elimination of carbon was the cause of the improvements, although direct evidence in the way of chemical analysis of the annealed test pieces was not yet obtainable for the reason that the methods available were not sufficiently accurate for this purpose, bearing in mind that 0.05 per cent means high carbon. On account of the great importance attributed to carbon a new method was developed for carbon analysis[10] whereby the sample to be analyzed could be heated first to 600 deg. cent. in vacuum and then to 1100 deg. in oxygen, and the resulting CO_2 frozen out in a liquid air trap and measured by the pressure exerted when evaporated into a known evacuated volume. An accuracy of ± 0.0001 per cent was obtainable by this method and this furnished the means for getting the desired data.

A number of samples of 2 per cent and 4 per cent silicon steels variously decarbonized, were tested and analyzed for carbon. The results completely verified the expectations, the curves for hysteresis loss vs. carbon content having the equation.

$$W_h = 5370 \times C^{.425} \quad (1)$$

for 4 per cent Si steel, and

$$W_h = 9650 \times C^{.493} \quad (2)$$

for 2 per cent Si steel.

These equations forming the first approximation to the true relationship between the magnetic properties and carbon, would, if correct for all carbon contents, lead to the startling conclusion that zero carbon should correspond to zero hysteresis loss and that carbon is the only factor affecting the magnetic properties, as none of the other impurities, nor the structural characteristics, was considered in plotting the above data. Before drawing such sweeping conclusions, however, it

7. Univ. of Ill., *Engr. Exp. Sta.*, Bull's 72, 77, 83, 95, 1914-17.

8. Wissenschaftliche Abhandlungen der Physikal. *Tech. Reichsanstalt*, Berlin, 1915-18.
ETZ. 36, pp. 675-77, 691-94 (1915).
Phys. Zeitschr. 19, pp. 434-36 (1918).
ETZ. Nos. 26 & 27 (1919).
Stahl u. Eisen, 41, p. 1249-54 (1921).
For a rod sample of electrolytic iron cut from a cathode sheet and annealed in a vacuum furnace at 1000 deg. cent. Gumlich obtained the very low coercive force of 0.115 gilberts cm. after subjecting it to a magnetizing force of $H = 150$; a value that has not been obtained for fused electrolytic iron. However, a value of $H_c = 0.10$ was obtained by the writer in 1915 for ring samples of 3.0 per cent Fe-Si Alloys. (See: University of Illinois *Eng. Exp. Sta. Bulletin* No. 83, p. 67, Table 13, or Trans. A. I. E. E., Vol. 34, p. 2664, Table 10).

9. A. I. M. E. *Trans.* 1913, p. 2805.

10. Carbon in Iron, *Trans.*, Am. Electrochem. Soc. 37, p. 227 (1920).

was deemed advisable to get more reliable data, to use test samples in the form of rings, and to determine carefully the effect of impurities like *S*, *P* and *Mn*

In order to cover the range of probable silicon contents it was decided to investigate the four series: 0, 2, 4, and 6 per cent silicon. The effect of *S*, *P* and *Mn* was investigated for the 0 and 4 per cent alloys only.

II. Hysteresis Loss

By the method of approximations, using a separate

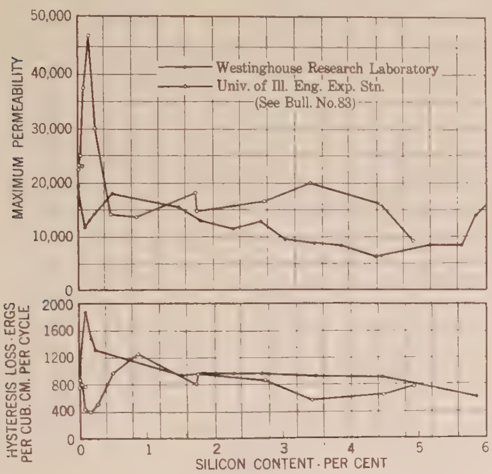

Fig. 1—Magnetic Properties of Iron-Silicon Alloys Annealed at 900 Deg. Cent. in Vacuo

set of test rings for each element, the effect of *S*, *P* and *Mn* was determined for 0 per cent Si and for 4 per cent Si alloys, the result being shown in Figs. 1 and 2, and can be expressed by the equations:

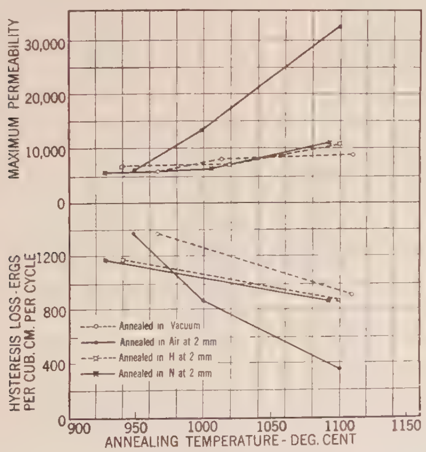

Fig. 2—Magnetic Properties of 4 Per Cent Iron-Silicon Alloys. Effect of Annealing in Vacuum, *N*, *H* or Air

For 0 per cent Si: $W_h = 18000 \times S + 13000 \times P + 1000 \times Mn$ (3)

For 4 per cent Si: $W_h = 12000 \times S - 4000 \times P + 800 \times Mn$ (4)

(Where W_h = hysteresis loss in ergs per cc. per cycle for $B = 10000$ gauss and *S*, *P*, *Mn* are percentages of these elements.)

By means of these results, the effect of *S*, *P* and *Mn* was eliminated from the total measured hysteresis loss of the main sets of alloys (using equation (3) for 0 and 2 per cent alloys and equation (4) for 4-6 per cent alloys) and thus obtaining the net loss due to carbon and structural characteristics,[11] as shown in Figs. 3 and 4 for 0 per cent Si: in Fig. 5 for 2 per cent Si: in Figs. 6 and 7 for 3.5 and 4 per cent Si; and in Fig. 8 for 5-6 per cent Si. In looking for the possible causes of the large deviations of some of the points from the curve for low carbon contents and bearing in mind in this connection the results obtained by Ruder[12] it was found that for constant low carbon contents ($C < 0.006$ per cent) there appears to be a fairly definite relationship between the hysteresis loss and grain size, expressible by the equation:

$$(N = \text{no. grains per sq. mm.}) \quad W_h = 65\sqrt{N} \tag{5}$$

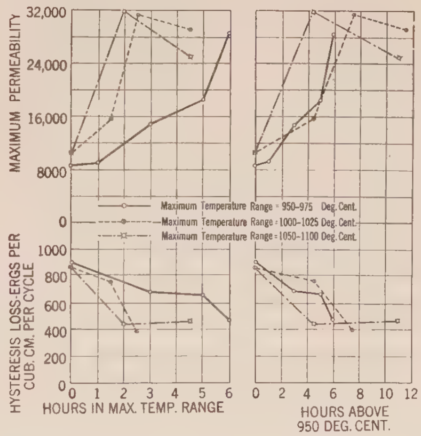

Fig. 3—Magnetic Properties of 4 Per Cent Iron-Silicon Alloys. Effect of Annealing of various Temperatures on Current of Air at 2 mm. Hg.

whereas for higher carbon contents ($C > 0.02$ per cent) the relationship can more nearly be expressed by the equation:

$$W_h = 3 \times N \tag{6}$$

By making corrections for grain size in accordance with these equations, it will be found that all the curves for hysteresis loss vs. carbon coincide for $C < 0.008$ per cent, irrespective of the silicon content.

$$W_h = 100000 \times C \tag{7}$$

What, at first, therefore appeared as a difference in the

11. The incidental impurities in the Fe-Si-C alloys were as follows:

S	0.001—0.026 per cent
P	0.002—0.005 per cent
Mn	0.001—0.005 per cent

12. *Loc. Cit.*

effect of carbon on Fe and Fe-Si alloys has resolved itself into a difference caused by the action of silicon:

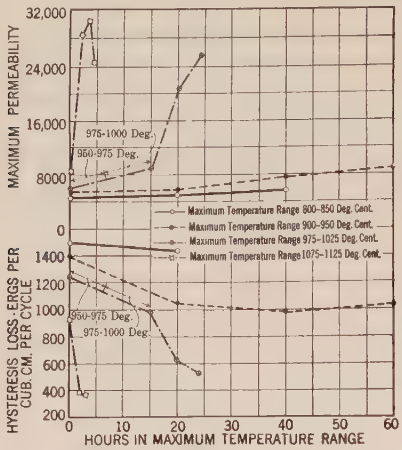

Fig. 4—Magnetic Properties of 4 Per Cent Iron-Silicon Alloys. Effect of Annealing in Current of Air at 10 hg. at various Temperatures

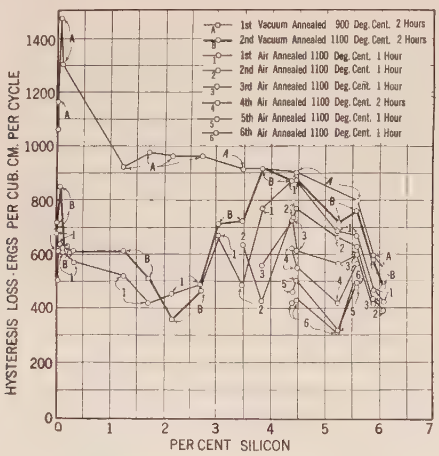

Fig. 5—Maximum Permeabilities of Iron-Silicon Alloys. Effect of Vacuum and Air Treatments

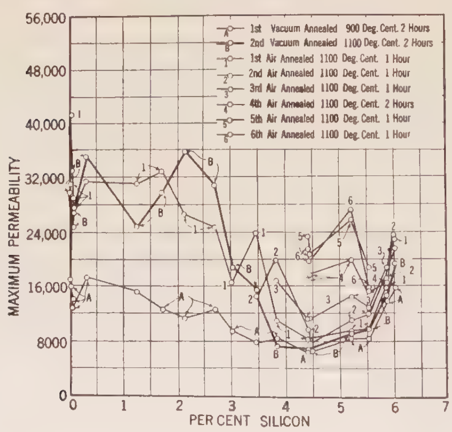

Fig. 6—Hysteresis Losses of Iron-Silicon Alloys. Effect of Vacuum and Air Treatments

First, by its action on the grain size, namely, that *without* silicon the normal grain size is small and it is difficult to get large grains, while *with* silicon (4 per cent) the normal grain size is large and small grains can be had only by severe mechanical working; second, by the action of silicon on the form of carbon, namely, by precipitating it as graphite instead of as pearlite for carbon contents in excess of about 0.08 per cent. The conclusion can, therefore, be drawn that the effect of carbon is the same on unalloyed iron and on 4 per cent

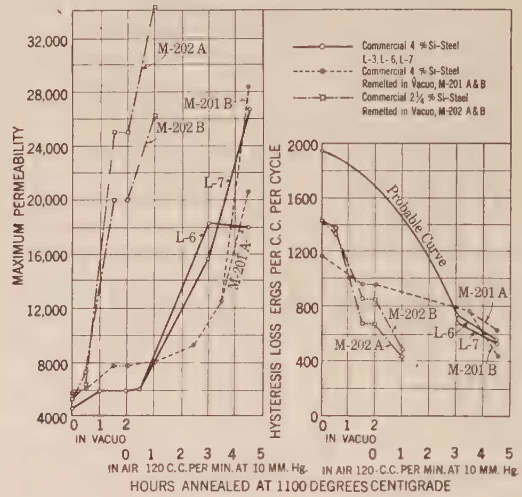

Fig. 7—Magnetic Properties of Commercial Silicon-Steel Effect of Annealing under Oxidizing Conditions at Reduced Pressure

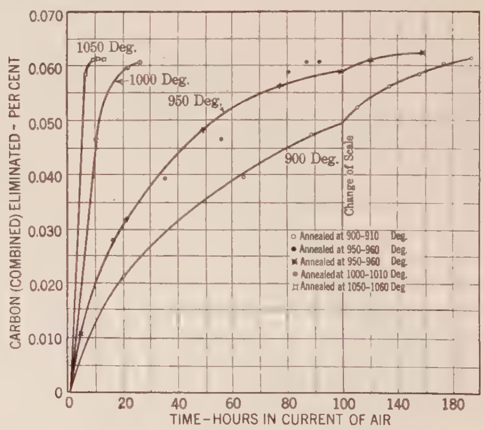

Fig. 8—Elimination of Carbon from 4 Per Cent Silicon Steel by Annealing in Current of Air at various Temperatures

Fe-Si alloys and depends only upon the form in which it occurs.

For higher carbon contents, the curves deviate a great deal as seen in Fig. 9, where all the curves have been redrawn for inter-comparison.

Form of Carbon

A great deal of consideration has been given to explaining these peculiar effects of carbon on the hysteresis loss. As the curves developed, it was naturally suggested that the various effects of carbon might be due to different forms in which carbon might exist in

the iron. Pearlite being the familiar form in slowly cooled iron, it was natural to suggest that this was the form in which carbon exists in unalloyed iron in the region 0.1 to 1.0 per cent. It was also thought, since the effect in the region 0.01 to 0.1 per cent was much less, that carbon here might be in the form of Fe_3C unassociated with ferrite. Finally, it was believed, on account of the tremendous effect of carbon in the region below 0.01 per cent, that carbon here must be in solution in the iron, entering into the crystal structure of the iron and distorting the space lattice and upsetting the equilibrium condition upon which the ferromagnetic properties depend.[13] The slope of the other curves above 0.01 per cent C suggested that for the 2 per cent Si alloys carbon becomes pearlitic immediately above 0.01 per cent instead of passing through the region of free Fe_3C between 0.01 and 0.10 per cent as in the case of 0 per cent Si. The horizontal curves for 4-6 per cent silicon suggested carbon as graphite, an inert material without any effect on the magnetic properties. The curve for 4 per cent Si, in the region 0.01-0.10, coincides with that for 0 per cent Si, indicating that carbon here might be in the form of Fe_3C. At that time the knee of the curves had not been definitely located, but it was known to be in the neighborhood of 0.01 per cent. In the meantime, Mr. N. B. Pilling had been investigating the problem metallographically and it was gratifying to find that his results substantially confirmed the original assumptions. According to his results, carbon is all in solution below 0.005 per cent, *i. e.*, there is no visible trace of precipitated material for lower carbon contents, even by using nitrobenzol etching reagent that attacks Fe_3C without attacking the ferrite, and 1000 diam. magnification. On the other hand, there is a possibility that carbon continues to go into solution to some extent above 0.005 per cent at the same time as it is partly precipitated, perhaps depending upon the annealing conditions. The shape of the curves (Figs. 3-7) indicates that there is no sharp dividing line, and subsequent evidence is to the effect that carbon continues to go into solution to some extent up to 0.02 per cent.

13. Since writing the manuscript for this paper, a very interesting contribution to the subject of solid solutions has been made by Dr. Walter Rosenhain: "Solid Solutions," issued with Mining and Metallurgy, June, 1923, *Trans.* A. I. M. E., 1923, Reprint No. 1250-N. In this paper Dr. Rosenhain explains the "Substitution" theory of solid solutions according to which atoms of various metals are capable of displacing each other in the space lattice of the crystal structure. The amount of solubility and the effect the solute has on the solvent will largely depend upon the relative properties of the atoms of the solute and the solvent. Such substitution would in any case result in some change in the forces between the adjacent atoms of the solvent, and some sort of distortion of the lattice is bound to follow, the more so the greater the difference between the two atoms. Most of the well known phenomena of solid solutions are satisfactorily explained by this theory. In regard to carbon and phosphorus Dr. Rosenhain believes that their atoms are so small compared with those of iron that they can find room in the lattice interstices, but, with effects similar to those of "substitution" atoms. It is readily seen that this theory harmonizes very well with the suggestion given above as to the action of dissolved carbon on the magnetic properties of iron. Dr. Rosenhain purposely avoids discussing the beneficial effect of silicon (and aluminum) on the hysteresis loss of iron, and merely remarks that this effect may be due to a neutralizing effect on the distortions caused by the impurities present. In view of the results given in the present paper it would seem, however, that the beneficial effect of silicon is independent of the impurities, and is due to the causes as stated in the above.

The Question of Grain Size and Intercrystalline Impurities

The question naturally arises: Why should the grain size affect the magnetic properties? There must be

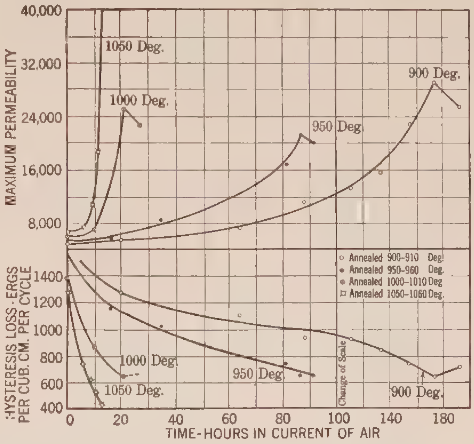

FIG. 9—MAGNETIC PROPERTIES OF 4 PER CENT SILICON STEEL AND THE EFFECT OF ANNEALING UNDER OXIDIZING CONDITIONS AT VARIOUS TEMPERATURES

something that increases as the grain size decreases, and upon which the hysteresis loss partly depends, or, in other words, that causes an increase in the hysteresis loss over and above that due directly to carbon and other impurities. As far as is known at present, there is only one material that increases as the grain size decreases and this is the amorphous intercrystalline cement, so called. It is, therefore, logical to conclude that there is a definite relation between the amount of this material and the hysteresis loss. It has been shown that the hysteresis loss per unit volume for alloys with carbon in solution is proportional to $\sqrt{N}$. It can also be shown that the amount of the intercrystalline material per unit volume is proportional to $\sqrt{N}$.[14] It follows, therefore, that the hysteresis loss

14. Assume that the grains are cubes and that the number of grains per mm.², N, is the same in every direction. Let the thickness of the cement be t mm. No. grains per mm.³ = $N^{3/2}$ and each grain has a volume of $1/N^{3/2}$ mm.³ Each grain is bounded by 6 faces of $1/N$ mm.² Assign one-half the thickness of the intercrystalline cement to each grain, then the volume of cement per grain is one-half $\times 6 \times t \times 1/N = 3\,t/N$ mm.³ Vol. of cement per cu. mm. $= 3\,t/N\ N^{3/2} = 3\,t\ \sqrt{N}$ mm.³ or vol. of cement per unit volume $= 3\,t\ \sqrt{N}$ units.

is directly proportional to the amount of the intercrystalline cement, and that the latter acts just like any other intercrystalline impurity, such as Fe_3C, pearlite, FeS, etc.

Another question that remains to be answered is in regard to the mechanism by means of which these intercrystalline impurities increase the hysteresis loss. Does the loss occur in the impurities themselves, or do they increase the loss in the ferrite grains by disturbing the uniformity of the flux distribution? Or, do they act merely as inert material, like graphite or air, having relatively speaking, no capacity for conducting a magnetic flux? In favor of the first suggestion speaks the fact that pure pearlite, consisting of Fe_3C and ferrite, has a maximum permeability of 1000 and a hysteresis loss of about 15,000 ergs, 13,500 of which is due to Fe_3C as pearlite (the remainder being due to carbon in solution). This is nearly 15 times the loss for iron saturated with carbon in solution. (0.006 – 0.008 per cent C). Now, pearlite consists of about 13.5 per cent Fe_3C and 86.5 per cent ferrite, and it is difficult to conceive how a reduction in the amount of active ferrite of only 13.5 per cent can possibly increase the flux density in any part to such an extent as to increase the hysteresis loss to 15 times the original value. On the other hand, how can we account for the difference in the effect on the hysteresis loss of Fe_3C as free cementite and of Fe_3C associated with ferrite as pearlite, the ratio of the former to the latter being as 1 to 7. Furthermore the permeability of Fe_3C, even at 1000 gauss (it saturates at less than 3000 gauss),[15] is so extremely low compared with that of ferrite with 0.008 per cent C at 10,000 gauss that the amount of flux passing through the Fe_3C would be very small, unless the Fe_3C formed a more or less continuous barrier across the flux path.

The only conclusion we can arrive at is, therefore, that there must be a hysteresis loss in the intercrystalline mpurities, including in this term the amorphous intercrystalline cement, and that the more or less continuous films formed by these impurities force the flux to pass through them, and furthermore, that more flux passes through the cementite when it occurs in the finely divided form of pearlite than when it occurs unassociated with the ferrite. It follows from this that the hysteresis loss of Fe_3C must be approximately

$$13500/0.135 = 100,000 \text{ ergs per cu. cm. per cycle.}$$

If Fe_3C saturates at a flux density of less than 3000 gauss, as stated by Honda, the flux density in the Fe_3C with 10,000 gauss in the pearlite (obtained by a magnetizing force of 15 gilberts) would be considerably less than 3000 gauss. Suppose, for the sake of calculation, that it is 2500 gauss in the Fe_3C, corresponding to a loss of 100,000 ergs. Applying Steinmetz' coefficient 1.6, the hypothetical loss corresponding to 10,000 gauss would be

$$W_{10} = W_{2.5}\,(10/2.5)^{1.6} = 100,000 \times 4^{1.6} = 913,000 \text{ ergs.}$$

Now, by regarding Fe_3C as 6.67 per cent carbon dissolved in iron, and applying the formula for dissolved carbon, (7) namely,

$$W_h = 100,000 \times C$$

the loss for pure Fe_3C for $B = 10,000$ gauss should be

$$W_{10} = 100,000 \times 6.67 = 667,000 \text{ ergs.}$$

While these two results differ considerably (25 per cent) it is interesting to note that by these two different methods of approach, we can arrive at figures for the loss of Fe_3C that are of the same order of magnitude, and that the hysteresis loss of Fe_3C should approach 1,000,000 ergs for a flux density of 10,000 gauss if such a flux density could be reached.

TABLE I

PROGRESS MADE IN RECENT YEARS

Year	Investigator	Kind of Material used	Maximum Permeability	Coercive Force gilberts per cm.		Hysteresis Loss ergs per cc. per ~*	
				For $B_{max} = 10000$	For $B_{max} = 15000$	For $B_{max} = 10000$	For $B_{max} = 15000$
1900	Hadfield	Sw. Char. Iron	4,000	0.920	1.00	abt. 2700	abt. 5500
1900	Hadfield	2½ per cent Si-Iron	5,100	0.72	0.79	" 2200	" 4700
1901	Gumlich & Schmidt	Wrought Iron	8,350		0.60		
1903	Baker	4.9 per cent Si-Iron			1.20		" 6200
1910	Terry	Electrolytic Iron	11,000				
1912	Gumlich & Goerens	0.4 per cent Si-Sheets	11,600		0.54		
1912	Gumlich & Goerens	4.0 per cent Si-Sheets	9,400				
1912	Paglianti	1.75 per cent Si-Iron		0.60	0.75	1650	3500
1914	Yensen	Pure Vacuum Iron	19,000		0.29	813	1640
1915	Yensen	0.15 per cent Si-Vacuum Iron	66,500	0.09	0.16	286	916
1915	Yensen	3.40 per cent Si-Vacuum Iron	63,300	0.08	0.15	280	1025

*1000 ergs/cub. cm./cycle = 0.80 watts/kg. at 60 cycles for 4% Si-Steel (Sp. Gr. 7.5) and = 0.76 watts/kg. for pure *Fe* (Sp. Gr. 7.9).

Calculation of Hysteresis Loss

The numerical coefficients for the effect of carbon on the hysteresis loss are given in Fig. 9 and by means of these, in conjunction with equations (3), (4), (5) and (6), the hysteresis loss for any Fe-Si-C alloy can be closely calculated from its composition and structural characteristics. Thus, in Table I, three different sets

15. Honda & Murakauri: Spec. Magnetism of Cementite, Tohoku University, *Sci. Repts.*, 6 p. 23-29, 1917.

of 4 per cent Si alloys of widely different characteristics have been tabulated together with their actual hysteresis loss and the loss as calculated from their composition and structure. While the maximum errors amount to ± 10 per cent it will be noted that the algebraic mean errors for the three sets are = 0.5 per cent, + 1.6 per cent, and 0 per cent respectively, and the mean error for all of the sets is only + 0.43 per cent, showing that by taking the mean for a few samples, the individual errors due to analysis are eliminated and very accurate results are obtained.

III. Coercive Force

While the hysteresis loss is a good criterion of magnetic quality, the coercive force vs. carbon for 0 per cent Si will be given because it serves to tie together the results of the present investigation with those obtained by the German investigators, Gumlich and Steinhaus in the *Physikalish Technischen Reichsanstalt.*[16]

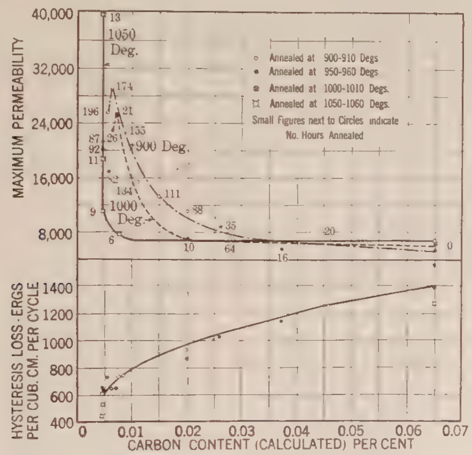

FIG. 10—MAGNETIC PROPERTIES VS. CARBON CONTENT. 4 PER CENT SILICON STEEL (N. 1 AW)

In discussing the effect of martensitic carbon, formed by quenching, on the coercive force, H_c, these investigators give the following figures:

0.01 per cent C as pearlite increases H_c by 0.07 gauss

0.01 per cent C as martensite increases H_c by 0.80 gauss

These results were obtained for medium and high carbon contents, as means were not available for analyzing very low carbon contents directly.

The present data in regard to coercive force have been plotted in Fig. 10, giving the following results:

For 0 – 0.006 per cent C: $H_c = 80 \times C$ *i. e.*, 0.01 per cent C produces a coercive force of 0.8 gilberts per cm.

For 0.01 – 0.09 per cent C: $\Delta H_c = 0.8 \times \Delta C$, *i. e.*, 0.01 per cent C increases H_c by 0.008 gilberts per cm.

For 0.10 – 0.90 per cent C: $\Delta H_c = 5.4 \times \Delta C$, *i. e.*, 0.01 per cent C increases H_c by 0.054 gilberts per cm.

Comparing these results with those obtained by Gumlich and Steinhaus, it is seen that our coefficient for carbon contents less than 0.006 per cent is just the same as theirs for martensitic carbon, (carbon in solution) thus confirming again our previous conclusion that carbon in amounts less than 0.006 – 0.008 per cent is all in solution.

In the case of pearlitic carbon, Gumlich and Steinhaus give $\Delta H_c = 7.0 \times \Delta C$, whereas the present data give $\Delta H_c = 5.4 \times \Delta C$. This disagreement is readily understood, if, as is probable, they assumed that all the carbon is precipitated as pearlite by cooling slowly from 900 deg. or above. On this assumption, by drawing a straight or slightly curved line from the origin through

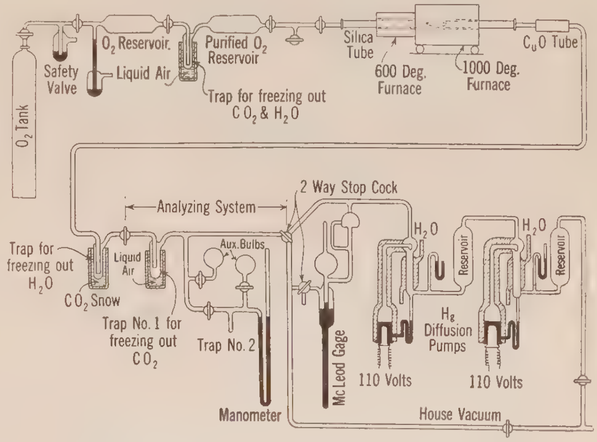

FIG. 11—APPARATUS FOR CARBON DETERMINATION

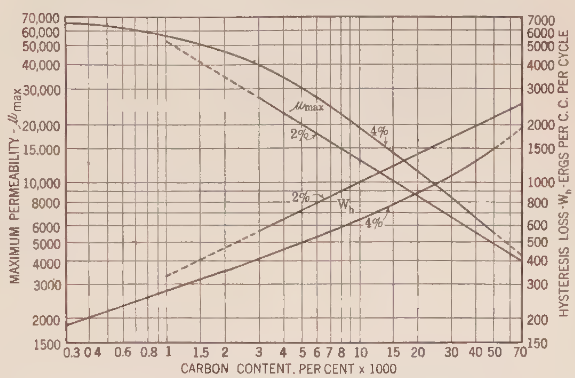

FIG. 12—MAGNETIC PROPERTIES VS. CARBON CONTENT, 2 PER CENT AND 4 PER CENT COMMERCIAL SILICON STEEL

the points obtained for H_c corresponding to carbon contents of 0.1 to 1.0 per cent, a coefficient of 7.0 can readily be obtained, but based on the present results this is obviously not correct.

IV. Permeability and Reluctivity

The maximum permeability of the Fe-C alloys has been plotted in Fig. 11 with carbon as abscissa. (No correction has been made here for the effect of incidental impurities). The general form of the curve for low and high carbon contents is seen to be that of a rectangular hyperbola, *i. e.*, $\mu_{max} \times C$ = constant. Therefore, by plotting minimum reluctivity ν_{min} $(= 1/\mu_{max})$

16. *ETZ*. 36, pp. 675-77, 691-94, 1915.

instead of μ_{max} a straight line will be obtained $1/\mu_{max} = \nu_{min} = C \times$ constant. In Fig. 12 ν_{min} has been plotted against per cent C, and it will be seen that the shape of this curve is almost identical with that of the curve for hysteresis loss (Figs. 3 and 4). As a matter of

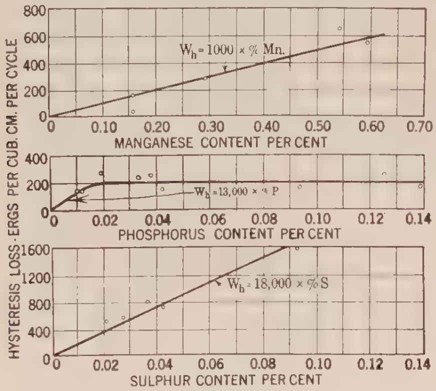

FIG. 13—EFFECT OF Mn, P AND S ON THE HYSTERESIS LOSS OF PURE IRON

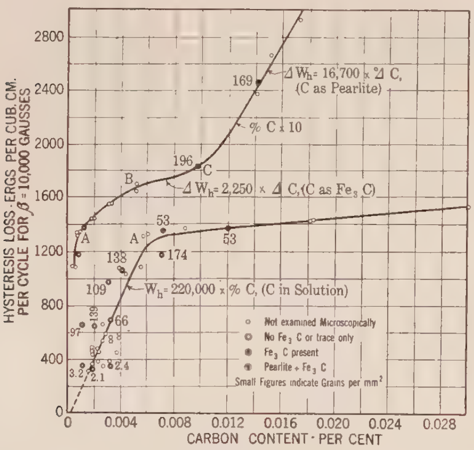

FIG. 14—EFFECT OF CARBON ON THE HYSTERESIS LOSS OF PURE IRON (EFFECT OF GRAIN SIZE NOT ELIMINATED)

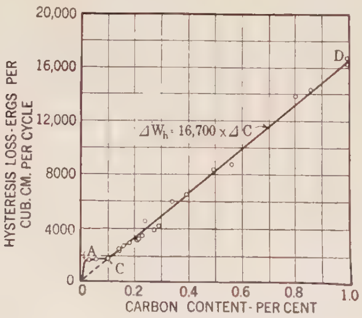

FIG. 15—EFFECT OF CARBON ON THE HYSTERESIS LOSS OF PURE IRON (EFFECT OF GRAIN SIZE NOT ELIMINATED)

fact, the ratio of the slopes of the various parts of the curve, $O\,A$; $B\,C$: $C\,D$ is 94.5: 1: 6.78 or nearly the same as for the hysteresis loss (98: 1: 7.4) and for the coercive force (100: 1: 7.6), Fig. 10. It must, therefore, be concluded that these three quantities: minimum reluctivity, hysteresis loss, and coercive force are all identical functions of the carbon content and of the state of carbon.

In Figs. 13, 14 and 15, the minimum reluctivity data have been plotted for 2 per cent, 4 per cent and 5-6 per cent Si respectively and in Fig. 16 all the curves thus obtained have been redrawn for comparison. While there are certain minor differences between these curves and those for hysteresis loss, the general shape is the same.

In Fig. 17 will be found representative B-H curves and other data for 0, 2, 4 and 6 per cent Fe-Si alloys

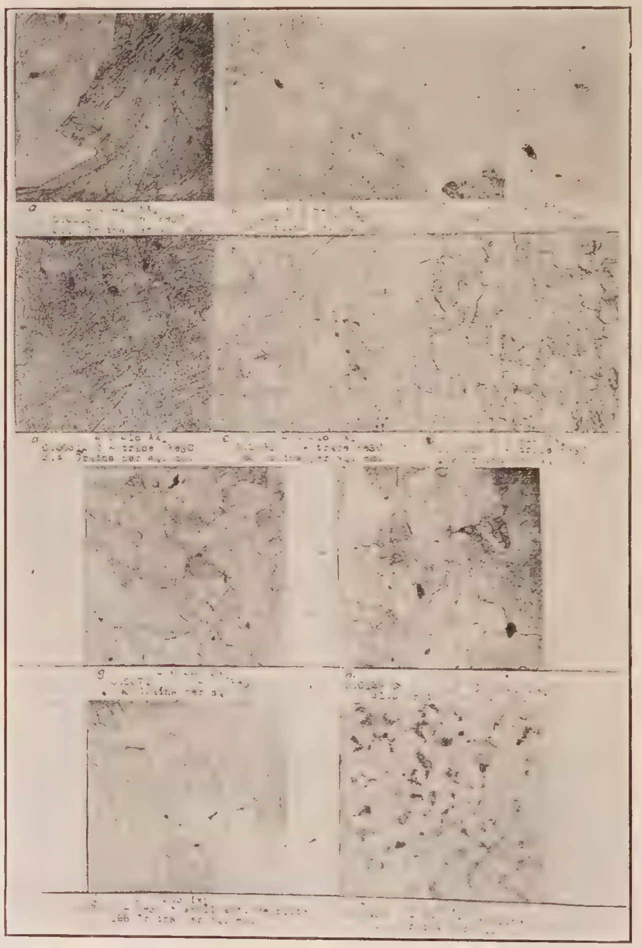

FIG. 16—FE-C ALLOYS. ETCHED WITH PICRIC ACID. 50 DIAM. CARBON DETERMINATION BY VACCUM-LIQUID AIR METHOD. FORM OF CARBON DETERMINED BY MEANS OF NITRO-BENZOL ETCHING REAGENT AND 1000 DIAM. MAGNIFICATION

with low carbon contents (0.002 – 0.003 per cent). The maximum permeability is practically the same for all of them, 25,000, but the high induction permeability and saturation value decrease in proportion to the silicon content. The hysteresis loss and coercive force are seen to be higher for the 0 per cent Si than for the other alloys on account of the smaller grain size.

V. Electrical Resistance

1. *Fe-C, Fe-Mn, Fe-S and Fe-P alloys.* The data in regard to electrical resistance have been plotted in Fig. 18, giving the following results:

1. Pure Fe has a resistance of 9.6 microhms per cu. cm. at 20 deg. cent.
2. With addition of Mn,
   $\rho = 9.6 + 7 \times Mn.$
3. With addition of S,
   $\rho = 9.6 + 12 \times S.$
4. With addition of P,
   $\rho = 9.6 + 60 \times P + 3.5 \times (P - .015).$

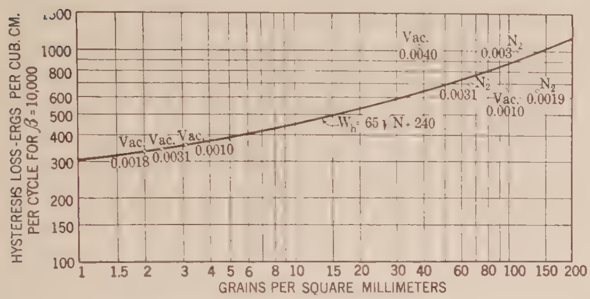

FIG. 17—HYSTERESIS LOSS VS. GRAIN SIZE FOR CARBON CONTENTS OF 0.001-0.004 PER CENT

Vac = Annealed in vacuo N_2 = Annealed in Nitrogen Small figures show carbon content.

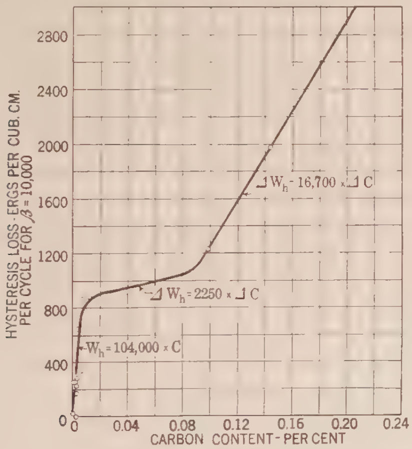

FIG. 18—EFFECT OF CARBON ON THE HYSTERESIS LOSS OF PURE IRON; EFFECT OF ALL OTHER IMPURITIES HAVING BEEN ELIMINATED

Upper limits $P = 0.015$ per cent $P = 0.12$ per cent.

5. With addition of C,
   $\rho = 9.6 + 82.5 \times C + 4.5 \times (C - 0.02)$

Upper limits $C = 0.02$ per cent $C = 0.85$ per cent.
C in Sol. C as Fe_3C and Pearlite.

Whether the sudden rise above 0.85 per cent C (the eutectoid point) is real or due to an experimental error can not be stated, because 1.0 per cent C was the limit of the carbon content. This same statement must be made in regard to the sudden rise in the curve for Fe-P alloys for $P > 0.12$ per cent. With these exceptions, these curves for electrical resistance in general check those for hysteresis loss as shown in Figs. 1, 2 and 3, and thus serve the useful purpose of confirming the conclusions on p. 8 in regard to the relationship between carbon and iron.

2. *Fe-Si Alloys.* The results obtained for 0-6 per cent Si are shown in Fig. 19.

This curve can be expressed in the form of an equation:

$$\rho = 9.6 + 18.4 \times Si + 11.1 \times (Si - 0.35)$$

Upper limits $Si = 0.35$ per cent $Si = 6$ per cent that is, the curve is composed of two straight lines with a slight bend at $Si = 0.35$ per cent.[17]

VI. Summary and Conclusion

1. Of the ordinary impurities in Fe and Fe-Si alloys, carbon has by far the most detrimental effect on the magnetic properties, because even in very slowly cooled materials it all exists in solution (martensite) in amounts up to 0.007-0.008 per cent, and continues

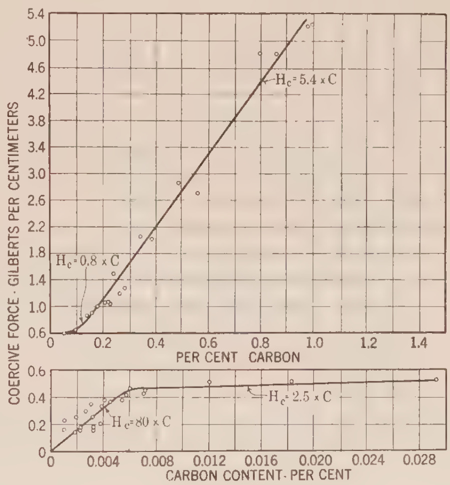

FIG. 19—COERCIVE FORCE VS. CARBON CONTENT FE-C ALLOYS. (EFFECT OF GRAIN SIZE NOT ELIMINATED)

to go into solution to some extent up to 0.02 per cent. Its effect on the magnetic properties of all Fe-Si alloys in this range is the same and as far as the hysteresis loss is concerned is expressed by the equation: (W_h = ergs per cu. cm. per cycle for B = 10,000 gauss, and C = carbon content in per cent).

$$W_h = 100{,}000 \times C.$$

2. In amounts greater than 0.007-0.008 per cent, in addition to the amounts in solution, carbon is precipitated in one or more of three forms; depending upon the Si-content (See Fig. 9).

(a) Graphite (in 4-6 per cent Si) with practically no effect.

(b) Fe_3C (in 0 and 4 per cent Si) with the effect: $\Delta W_h = 2250 \times \Delta C$.

17. The solid points were obtained by the writer at the University of Illinois in 1915. (See Bull. No. 83, *Eng. Exp. Sta.*)

(c) Pearlite (in 0 and 2 per cent Si) with the effect $\Delta W_h = 16{,}500 \times \Delta C$.

3. Of the other impurities, sulphur has the most detrimental effect: $W_h = 18{,}000 \times S$ for 0 per cent Si and $W_h = 12{,}000 \times S$ for 4 per cent Si and should be eliminated as far as possible. Mn in small amounts is harmless, and P, while detrimental to a limited amount (0.016 per cent) for 0 per cent Si, is actually beneficial for 4 per cent Si.

4. In addition to the ordinary impurities, it has been found that the magnetic properties depend to a large extent upon the grain structure, in particular upon the intercrystalline amorphous cement. Denoting the number of grains per sq. mm. by N, it has been shown that for low carbon contents (for carbon in solution) the effect of grain size on the hysteresis loss may be expressed approximately by the formula:

$$W_h = 65\sqrt{N},$$

whereas for precipitated carbon the effect may be expressed more nearly by the formula:

$$W_h = 3\,N.$$

5. The hysteresis loss of any Fe-Si-C alloy, containing the ordinary impurities, S, P and Mn in small amounts, as for instance commercial electrical steels, can be calculated with a good degree of accuracy by means of the relationships given above, using for this purpose the same constants for 0 and 2 per cent silicon and 4-6 per cent silicon.

6. The evidence obtained is to the effect that the increased hysteresis loss, due to carbon and other impurities that are precipitated combined with iron, is caused by the inherent hysteresis loss of these precipitated impurities.

7. As it is found that the hysteresis loss (for carbon in solution) is proportional to the amount of the intercrystalline amorphous material, it is concluded that the latter can be regarded as belonging to the same class as the precipitated impurities, and that the increased hysteresis loss, due to decreased grain size consequently is caused by the inherent hysteresis loss of this amorphous material.

8. Regarding the tremendous effect of carbon in solution, it is suggested that this is due to the entering of carbon, into the more or less stable equilibrium arrangement of the ferro-magnetic structure, and upsetting this equilibrium arrangement.

9. The conclusions reached by means of the hysteresis loss are confirmed by the results obtained for the coercive force, minimum reluctivity and electrical resistance.

10. An attempt has been made in this investigation to separate the various factors influencing the magnetic properties. On account of the large number of factors involved and the large number of separate steps required to obtain the data for the various sets of samples, the conclusion may in some individual case be based on what may seem insufficient evidence. However, if the results are viewed as a whole it will be seen that evidence in one part of the investigation can be used to strengthen evidence in other parts that may seem rather scant if taken by itself. The writer does not wish that the results be considered as final in regard to the various factors affecting the magnetic properties, but it is firmly believed that they are qualitatively correct and that they have opened a new path in the unexplored region of magnetism that may be of service in the further exploration of the same.

Acknowledgements

The alloys were prepared partly by Mr. E. F. Long, partly by Mr. A. A. Frey and partly by the writer; the annealing has been attended to largely by Mr. D. C. Mayne; the carbon analysis has been done partly by Mr. A. L. Shields and partly by Mr. D. C. Mayne.

The magnetic testing has been done under the direction of Mr. Thomas Spooner; the chemical analysis, other than the carbon analysis, under the direction of Mr. C. J. Rodman; and the micro-analysis under the direction of Mr. N. B. Pilling.

All of the above work has been done in the Research Laboratory under conditions insuring great accuracy and the results are therefore believed to be as reliable as is possible with the time and money available. The writer feels greatly indebted to all the above colleagues and takes this occasion to express his appreciation for their valuable cooperation.

ADJUSTMENT OF AUTOMOBILE HEADLIGHTS

An interesting feature of the recent Chicago Motor Show was an exhibit showing how headlights ought to be adjusted. This booth was arranged by the Bureau of Standards in cooperation with the Society of Automotive Engineers and the Chicago Motor Club. An automatic projection machine was employed to give further instruction. Pamphlets prepared by the Bureau and printed by the National Automobile Chamber of Commerce were likewise distributed.

The booth attracted a large number of visitors and it is believed that it served a useful purpose.

At the request of the Tidewater Automobile Association, which is affiliated with the American Automobile Association, the Bureau gave a demonstration of the bad effects of dimming headlights as opposed to properly adjusted lights before a special committee of the Virginia State Senate. This is of importance since a change in the Virginia law requiring the dimming of lights when motor cars are passing was under consideration. After the demonstration, which brought out very clearly the undesirability of the proposed legislation, the Bureau was asked to appear before the General Laws and Rate Committee and recommended certain changes in the enforcement of the present law, which it is believed will produce better results.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

LIGHTING STATISTICS OF REPRESENTATIVE URBAN AND SUBURBAN HOMES*

BY NORMAN D. MACDONALD

INTRODUCTION

During the summer of 1921 the Association of Edison Illuminating Companies through a subcommittee of its Lamp Committee engaged in a survey of residence service conditions in certain cities in which member companies of that Association operate.

The illuminating engineering data which form only a part of the information obtained were secured as one means towards this end. The data secured were necessarily limited, but it is felt that most of the information is accurate and dependable and may be used as a base line for the measurement of future progress.

Where, however, the returns rest upon the surveyor's judgment, there is, of course, some question of reliability.

Extent of Survey.—This survey was participated in by

The New York Edison Company

The United Electric Light & Power Co. of New York

Commonwealth Edison Co. of Chicago

Edison Electric Illuminating Co. of Boston

Rochester Gas and Electric Corporation

The Detroit Edison Company.

The statistics were analyzed by the Electrical Testing Laboratories.

For each company, two hundred and fifty residences were chosen whose yearly bills were estimated to approximate the average for residence consumption of electricity in the city.

General Statistics.—In this paper the data will be indicated for the average of the houses, or the average of the apartments, all cities being combined. The following table contains general statistics underlying the deduced data which will be shown hereafter:

TABLE I.
STATISTICS OF RESIDENTIAL INSTALLATIONS

	**Average no. rooms	Average *area sq. ft.	Average no. people	Average no. operative lamps	Total watts lighting installation	No. surveyed
APARTMENTS						
High city	†9.9	1,117	4.3	17.5	856	273
Average	7.8	831	3.6	14.7	664	144
Low city	‡6.1	563	2.9	10.9	502	52
HOUSES						
High city	12.2	1,550	4.9	21.0	950	222
Average	10.4	1,232	4.6	19.4	859	138
Low city	9.3	1,047	4.2	16.9	760	61

*Exclusive of attics and cellars.

**Includes any lighted area enclosed by walls, such as halls, closets, baths, etc.

†"High city" indicates the highest average value for any one city.

‡"Low city" indicates the lowest average value for any one city.

Abstract of a paper presented at the 1922 Convention Illuminating Engineering Society, Swampscott, Mass.

TABLE II.
AREA OF ROOM IN SQUARE FEET

	Hall	Living	Dining	Kitchen	Bed	Bath
APARTMENTS						
High city	76	183	162	126	138	55
Average	66	164	152	108	116	45
Low city	55	141	134	73	93	30
HOUSES						
High city	83	197	172	147	156	59
Average	71	190	166	130	132	55
Low city	49	181	160	116	121	53

Sizes of Lamps (Table I).—The distribution diagrams shown in this table indicate the predominance of the vacuum type lamp of the 25 to 60-watt ranges. There is no general use, at the present time, of gas-filled lamps. The average watts of the lamps in apartments is 45.3 and in houses is 44.1.

TABLE III
WATTS OF LAMPS INSTALLED PER SQUARE FOOT OF ROOM AREA AVERAGE OF ALL CITIES

Type of residence	Halls	Living room	Dining room	Kitchen	Bed room	Bath
Apartments	0.73	1.16	0.95	0.59	0.60	1.15
Houses	0.67	1.09	0.82	0.53	0.44	0.89

These data are determined from the operative lamps installed in the various rooms shown. The figures approximate the watts per square foot used in lighting these rooms with the possible exceptions of the dining and living rooms where it is found that normally only a portion of the total installation is used. Later data from another source fix the per cent of lamps normally used at from 66 to 75 per cent for such rooms.

One resaon for the low watts per square foot of used equipment in dining and living rooms is the spotty character of the illumination. In general, fairly high illumination is found on the dining table and at the center of the living room. The intensities fall off rapidly as the sides of the room are approached.

TABLE IV
REPRESENTATIVE FOOT-CANDLES—DAY AND NIGHT

	Apartments				Houses			
	Daylight		Artificial		Daylight		Artificial	
Rooms	No. rooms meas.	Avg. ft. cand.	No. rooms meas.	Avg. ft. cand.	No. rooms meas.	Avg. ft. cand.	No. rooms meas.	Avg. ft. cand.
Halls	676	1.2	130	1.7	684	1.6	77	1.7
Living rooms	662	8.9	98	4.1	433	3.4	59	4.2
Dining rooms	599	6.1	87	3.6	434	3.4	68	4.8
Kitchens	704	7.2	75	3.6	453	4.5	70	4.1
Bedrooms	1,652	6.7	205	2.6	1,499	3.3	220	3.1
Baths	737	6.5	84	3.2	434	3.2	70	5.0

Wall Decoration and Daylight.—In both apartments and houses there is a tendency to use dark decorations in dining rooms, living rooms and halls. In general, the proportions of respectively light, medium and dark decorations are as those of good, fair and poor natural lighting. The tendency, is to assist the natural lighting in bed and bath rooms with decorations of light tone.

A greater proportion of dark decorations was found in poorly lighted rooms.

Uses of Lighting Sockets.—About 5 per cent of the total number of fixed lighting sockets are found to have been fitted with cord and plug to lead the current to some more convenient point for use in either a portable lamp or appliance.

Of the sockets remaining for strictly lighting use, 85 per cent are used in lighting; 1 per cent contain burned out or broken lamps, 3 per cent are empty, although normally in use, and 11 per cent are empty through disuse. This last figure is usually explained through the obsolescence of some sockets of the rigid luminaires, through the substitution of gas-filled lamps, using fewer sockets, or through the substitution of portable lamps.

TABLE V
STATISTICS OF USES OF LIGHTING SOCKETS IN RESIDENCES

			Distribution of sockets less those devoted to cord and plug			
	Per cent sockets devoted to cord and plug	Total remaining sockets surveyed	Containing lamps: Operative	Containing lamps: Burned out or broken	Empty: Ordinarily used	Empty: Not used
APARTMENTS						
High city	7.5	3530	88.5	1.7	6.3	16.4
Average	5.3	2387	83.9	0.9	3.3	11.9
Low city	3.3	990	79.4	0.0	1.3	8.1
HOUSES						
High city	7.4	5189	92.0	1.4	2.8	13.3
Average	5.2	3163	86.8	0.8	2.3	10.1
Low city	3.1	1219	81.0	0.2	1.4	8.4

Accessibility of Lamps.—The statistics collected indicate that in 75 per cent of the cases lamps may easily be removed from fixtures and that in the other 25 per cent the changing is attended by some inconvenience.

Wall or Baseboard Receptacles in Various Rooms (Table III).—The wall or baseboard receptacle or "convenience outlet" to use the newly coined term, is employed in only one-quarter to one-half the cases where it might be used. A very striking feature in this chart is the difference in the use of "convenience outlets" in apartments and houses. The houses have twice as many outlets as the apartments.

Classification of Luminaires (Table IV).—The diagram shown illustrates the luminaires which are in constant use. For instance, the 9.3 per cent of living rooms in apartments which are illuminated by table portables probably have installed some form of chandelier or wall brackets, but in all cases our inspectors were informed that the table portable was the only unit in regular use. If a chandelier was used usually with the portable, the living room was classed with the group called "Central Fixture with Portable." It is interesting to note that the shower is the most popular luminaire in apartments, and that in houses the table portable is the largest single factor, the shower being used only half as generally as in apartments. It is possible that the inexpensiveness of the shower is one cause of its popularity.

Portable Connected to Luminaire.—In approximately one-third of the living rooms, both apartments and houses, a portable lamp is connected to the fixture. This may be the result of several different causes.

Visibility of Bare Lamps (Table V).—Inspectors were instructed to look at each lighting unit in living rooms from a number of the most used portions of the room. In about one-half of the cases bare lamps were found to be within the line of vision, the percentage being about 60 in apartments and 40 in houses. This is a very important finding, as it indicates that in our campaign of education we have not as yet persuaded the householder of the objectionable character of glaring sources.

CONCLUSIONS

In summing up the data which have been presented, we find that the average central station customer lives in a dwelling of nine enclosed spaces (probably five rooms, bath, two halls and a closet) of about 1000 sq. ft. in area. He uses about sixteen incandescent lamps of the 25 to 60-watt sizes. There are three to four persons in the family (average 3.6). The rooms vary in size from 45 sq. ft. to 190 sq. ft. The rooms in general are illuminated in spots, but the watts per square foot indicate that the general illumination is low, although the most used portions of the rooms are fairly well illuminated. The customer selects home decorations from the viewpoint of custom or appearance and pays relatively little attention to their influence upon illumination. He has far too few convenience out-lets and therefore used drop cords for table lamps and appliances. He needs 4 per cent more lamps at once to replace outages and has not been taught the value of keeping spare lamps on hand. He has abandoned 11 per cent of his original installation as unsatisfactory or superfluous.

Owing to height or inconvenience, he has trouble in replacing 25 per cent of his bulbs. He needs to be taught the value of light reflecting decorations and that his lighting appliances need to be cleaned as often as his windows. And last, and most important, he is unadvised of the advances in lighting practise of the past few years, and of his own need of proper modern lighting equipment, as in the majority of cases the luminaires found are of the same period as the house. A rough estimate would indicate that less than 10 per cent of the luminaires reflect modern engineering thought. This is further emphasized by the fact that in living rooms 50 per cent of the lamps are so placed that bare lamps are in the line of vision, and in 33 per cent of these rooms portable lamps have been introduced to improve the original installation.

DAVY'S FIRST CARBON ARC LAMP

In 1809 Sir Humphrey Davy demonstrated before the Royal Society, London, that an arc light could be produced by touching two sticks of carbon connected to a 2000-cell electric battery. It is estimated that it cost six dollars a minute to operate this forerunner of modern electric illumination.

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Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

A. I. E. E. Annual Convention

GOOD PAPERS AND PLEASANT ENTERTAINMENT TO FEATURE JUNE MEETING

Excellent papers and enjoyable entertainment are assured those who attend the Annual Convention at Edgewater Beach, Chicago, June 23-27. Among the subjects treated in the papers are distribution, cables, automatic stations, reactors, communication, electrophysics, street lighting and electrical machinery. There will also be annual reports by the Technical Committees and several Standards Sub-committees as well as addresses on Standards by well-known speakers. The Section delegates will hold a meeting all day on Monday.

Sports and Entertainment

This convention will be held in a most favorable location just outside of the congested city districts of Chicago on the shore of Lake Michigan. The Edgewater Beach Hotel offers many attractions for sports and social affairs. Golf courses and tennis courts are close at hand and it is probable that tournaments will be arranged. Bathing in Lake Michigan may also be enjoyed and plans are being made for other water sports. Card parties, teas and sightseeing trips are being planned for the ladies and orchestras will furnish music for dancing during the afternoons and evenings.

On Tuesday evening the President of the Institute will hold a reception which will be followed by dancing. On Thursday evening an enjoyable entertainment feature called "With the Fairies" will be staged.

On Tuesday at 6 p. m. a conference and dinner will be held by the Educational Committee to which all members interested in education are invited.

To add to the sociability of the convention, one hour each day, starting at 9 a. m., has been set aside as a "Social Hour" during which members may meet in the less formal ways for friendly conversation and discussion.

Interesting Trips

Chicago and its vicinity hold many features of interest to the electrical engineer and a number of inspection trips will be made. The members will have an opportunity to visit the

THE WAUKEGAN STATION OF THE PUBLIC SERVICE COMPANY OF NORTHERN ILLINOIS. THE STATION IS PLANNED FOR AN ULTIMATE CAPACITY OF APPROXIMATELY 200,000-KW. AND WILL BE ONE OF THE CHAIN OF PLANTS, INCLUDING THE COMMONWEALTH EDISON PLANTS AND A NEW PLANT TO BE ESTABLISHED AT THE FOOT OF LAKE MICHIGAN ON THE ILLINOIS-INDIANA STATE LINE, TO SERVE THE CHICAGO DISTRICT.

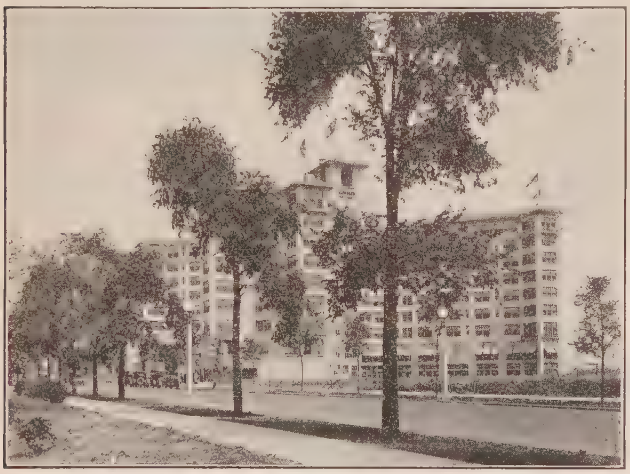
THE FIRST SECTION IN THE 132,000-VOLT, 60-CYCLE, 3-PHASE TIE LINE THAT WILL LINK THE PLANTS SUPPLYING THE CHICAGO DISTRICT WITH ELECTRICAL ENERGY. THIS IS A VIEW OF THE LINE FROM THE WAUKEGAN PLANT OF THE PUBLIC SERVICE COMPANY OF NORTHERN ILLINOIS TO EVANSTON.

automatic substation in Evanston, a new automatic telephone exchange, the Hawthorne plant of the Western Electric Company, the Gary Steel Works, the Pullman Company's plant and the Waukegan plant of the Public Service Company of Northern Illinois, besides all stations of the Commonwealth Edison Company.

There will be a delightful boat trip to Calumet, an automobile trip through Chicago's boulevards, a visit to the new Field Museum and other interesting trips.

The Edgewater Beach Hotel is less than an hour's ride from the heart of Chicago's business district. For the convention there will be a special rate of $3.00 per day for single rooms and $3.00 per day for those sharing rooms and suites. All of the rooms are outside and have private baths. The plan of the hotel is European, having two excellent restaurants in connection. Persons wishing to obtain accommodations for the convention should send in their reservations to the Edgewater Beach Hotel, 5300 Sheridan Road, Chicago, Ill., as soon as possible. Garage space for automobiles will be available and reservations should be made for this also.

The Convention Committee which is arranging the meeting is composed of the following gentlemen: Messrs. R. F. Schuchardt, Chairman, J. E. Kearns, A. W. Berresford, L. A. Ferguson, M. M. Fowler, C. H. Jones, Ernest Lunn, H. A. Lynette, J. C. Martin, T. Milton, L. W. W. Morrow, S. A. Rhodes, D. W. Roper C. C. Grandy, Geo. E. Wagner, Ellery B. Paine, D. C. Pyke, S. H. Mortensen, E. L. Bailey and H. W. Meyer.



Edgewater Beach Hotel. Headquarters for the A. I. E. E. Annual Convention

The following is a detailed program of papers and events.

TENTATIVE PROGRAM FOR ANNUAL CONVENTION

Monday, June 23

10:00 a. m.

Section Delegates and Committee Meetings.

2:30 p. m.

Section Delegates and Committee Meetings

8:00 p. m.

Informal Dance

Tuesday, June 24

9:00 a. m.

Social Hour

10:00 a. m.

President's Address and Report of Technical Committees

2:00 p. m.

Sports and Entertainments

6:00 p. m.

Educational Committee's Informal Dinner and Conference

8:00 p. m.

President's Reception and Dance

Wednesday, June 25

9:00 a. m.

Social Hour

10:00 a. m.

Two Parallel Technical Sessions

Session A, under Auspices of Protective Devices Committee, H. R. Woodrow, Chairman

Automatic Stations for A-C. and D-C. Networks, by C. W. Place, General Electric Company.

The Cleveland Heights Substation of The Cleveland Electric Illuminating Company, by H. L. Wallau, The Cleveland Electric Illuminating Co.

Automatic Substations for Supplying 1500 Volts D-C. to Suburban Railways, by C. A. Butcher, Westinghouse Elec. & Mfg. Co.

Automatic Motor-Generator Equipments on Edison Service of The Indianapolis Light & Heat Co., by Herman Bany, General Electric Co.

Operating Experience with Automatic Equipment on an Edison System, by F. D. Wyatt, The Union Gas & Electric Co.

Automatically Controlled Hydroelectric Generating Stations, by R. J. Wensley, Westinghouse Elec. & Mfg. Co.

Session B, under Auspices of Telegraphy and Telephony Committee, O. B. Blackwell, Chairman; and Electrophysics Committee, F. W. Peek, Jr., Chairman

Selective Circuits and Static Interference, by J. R. Carson, American Telephone & Telegraph Co.

The Transmission Unit and Telephone Transmission Reference Systems, by W. H. Martin, American Telephone and Telegraph Co.

Sensitive Radio-Frequency Relay, by George Lewis, Crosby Manufacturing Co.

The Transient Visualizer, by H. M. Turner, Yale University.

Temperature Rise of Stationary Electrical Apparatus as Influenced by Radiation, Convection and Altitude, by V. M. Montsinger and W. H. Cooney, General Electric Co.

Effect of Altitude on Temperature Rise of Electrical Apparatus, by R. E. Doherty and E. S. Carter, General Electric Co.

2:00 p. m.

Sports and Entertainment

7:30 p. m.

Meeting under Auspices of the Standards Committee, H. S. Osborne, Chairman.

Address, by A. W. Whitney, Chairman, American Engineering Standards Committee.

Standards of the A. I. E. E.—Brief Presentation for Discussion of Certain Sections of the Proposed Revised A. I. E. E. Standards, by the chairmen of the working committees as listed below.

Standards for Transformers, Induction Regulators and Reactors, by John D. Bowles.

Standards for Synchronous Converters, by John C. Parker.

Standards for Industrial Control Apparatus, by H. D. James.

Standards for Electric Arc Welding Apparatus, by F. M. Farmer.

Standards for Insulators, by R. E. Argersinger.

Thursday, June 26

9:00 a. m.—Social Hour

10:00 a. m.—Two parallel technical sessions

Session A, under Auspices of Transmission and Distribution Committee, F. G. Baum, Chairman

Underground A-c. Network Distribution, by A. H. Kehoe, United Electric Light and Power Co.

General Light and Power Supply of Chicago, by G. M. Armbrust and J. B. Jackson, Commonwealth Edison Co.

Study of Underground Distribution Systems, by W. R. Bullard, New Orleans Public Service.

Equivalent Single-Phase Networks for Calculating Three-Phase Short-Circuit Currents, by R. A. Shetzline, American Telephone and Telegraph Co.

Standardization in Construction and Operation, by M. L. Sindeband, American Gas and Electric Co.

Session B, under Auspices of Protective Devices Committee, H. R. Woodrow, Chairman

Current-Limiting Reactor Characteristics, by S. I. Oesterreicher, Metropolitan Device Corp.

Design, Installation and Operation of Current-Limiting Reactors, by H. O. Stephens and F. H. Kierstead, General Electric Company.

Current-Limiting Reactors, by W. M. Dann, Westinghouse Electric & Mfg. Co.

Theory of the Saturated-Core Regulator and Reactor, by A. Boyajian, General Electric Company.

Application of the Saturated-Core Regulator and Reactor, by D. K. Blake, General Electric Company.

2:00 p. m.—Sports and Entertainments

7:30 p. m.—"With the Fairies."

Friday, June 27

9:00 a. m.—Social Hour

10:00 a. m.—Two parallel technical sessions.

Session A, under Auspices of Electrophysics Committee, F. W. Peek, Jr., Chairman; and Lighting and Illumination Committee, G. H. Stickney, Chairman

High-Voltage Cables, by Wm. A. Del Mar and C. F. Hanson, Habirshaw Electric Cable Co.

The Dielectric Field in an Electric Power Cable, by R. W. Atkinson, Standard Underground Cable Co.

Direct Method of Calculating Capacitance of Conductors, by H. B. Dwight, Canadian Westinghouse Co.

Improved Method of Measuring Potential Gradient and Flux Density in Irregular Fields, by J. F. H. Douglas and E. W. Kane, both of Marquette University.

Some Notes on Street Lighting, by Preston Millar, Electrical Testing Laboratories.

Session B, under Auspices of Electrical Machinery Committee, H. M. Hobart, Chairman

Flashing Characteristics of Series and Compound Motors, by R. E. Ferris, Westinghouse Elec. & Mfg. Co.

The 35,000-kw. Frequency Converter for Hell Gate Station, by O. E. Shirley, General Electric Co.

The Inertaire Transformer, by W. M. Dann and D. R. Kellogg, Westinghouse Electric & Mfg. Co.

A New Type of Single-Phase Motor, by S. R. Bergman, General Electric Co.

Theory and Calculation of the Squirrel-Cage Repulsion Motor, by H. R. West, General Electric Co.

Attractions of the Pasadena Meeting

Interesting sessions and the charm of California are the forces which will draw many members of the Institute to the Fall meeting at Pasadena, October 13 to 17. To the members in the eastern part of the country the proposed excursion trip to the Coast with stops at many noted places will give also an additional incentive to attend. (See the Journal for April, page 386.)

The technical papers will be presented by engineers from both the West and the East. For the Eastern authors it is planned to have speakers who are nationally known in their respective fields, and the Western authors will be the experts from that section of the country. Transmission is, of course, one of the livest subjects on the Pacific Coast and there will be several papers on this topic by well-known specialists. Distribution, too, will be covered as well as generation and electric machinery.

As there are many engineers in the West who are interested primarily in the application and utilization of electricity, this field will be covered by a number of papers. Among the applications which will be treated are lumbering, irrigation, mining, oil fields and factories.

It is very fortunate that the meeting will be held in Pasadena in which is located the famous laboratory of Dr. R. A. Millikan, the Norman Bridge Laboratory of the California Institute of Technology. As a special feature Dr. Millikan and his colleagues will present papers and demonstrations on their researches in electrophysics.

Another feature of the program will be a meeting in which many well-known pioneers of the Institute and other prominent men will take part. This should be of particular interest to many of the members.

Social events will add to the attractiveness of the meeting as will the trips which have been planned to Mt. Wilson and other noted places.

An enthusiastic Convention Committee is working towards carrying out the plans as mentioned here to make the meeting a really national event. The members of the committee are as follows: Messrs. R. W. Sorenson, Chairman, O. F. Johnson, Secretary, M. O. Bolser, E. E. F. Creighton, H. B. Dwight, E. R. Hannibal, C. R. Higson, W. C. Heston, C. W. Koiner, J. A. Koontz, Jr., C. A. Lund, F. W. MacNeill, S. G. McMeen, L. W. W. Morrow, E. F. Pearson and E. R. Stauffacher.

Northeastern District to Hold Two-Day Regional Meeting

A convention of a new type will be held under the auspices of the Northeastern District at Worcester, Mass., on June 5 and 6. Three technical sessions and several special features including an address by President H. J. Ryan have been scheduled for this meeting. All members of the Institute who can attend the meeting are cordially invited.

A diversity of subjects is covered in the technical papers which include transmission, vacuum tubes and radio temperature measurements, insulators, transformers for testing purposes, electrical machinery and windmill generation of electric energy. The special addresses and other features have been scheduled to follow a banquet on Thursday evening. The Electrical Machinery Committee is taking advantage of the meeting to hold a conference on Friday afternoon.

Among the trips which have been arranged there will be a visit to Worcester Polytechnic Institute on Friday afternoon besides excursions to industrial plants in the neighborhood.

This meeting has been planned through the combined efforts

of the several Sections in the Northeastern District working under the Vice-president of the District. Much interest is being shown and a large attendance is expected from both the district and other Sections.

The following is the program which has been planned.

PROBABLE PROGRAM OF NORTHEASTERN DISTRICT MEETING AT WORCESTER, MASS., JUNE 5 AND 6

THURSDAY, JUNE 5

9:00 A. M.

Registration, Electrical Engineering Department Library, Worcester, Polytechnic Institute.

10:00 A. M.

TECHNICAL SESSION—LECTURE ROOM, ELECTRICAL ENGINEERING DEPARTMENT, WORCESTER POLYTECHNIC INSTITUTE

Very Large Transmission Systems, by Percy Thomas, Consulting Engineer.

The Functions, Applications and Construction of the Various Vacuum Tubes, by Dr. A. W. Hull, General Electric Co.

Thermotel, by E. D. Treanor, General Electric Co.

Windmill Generator Plants, by F. C. Doughman, Westinghouse Electric & Manufacturing Co.

2:00 P. M.

Excursion to Industrial Plants
Recreation
Meeting of Executive Committee of Northeastern District

6:30 P. M.

Banquet—Bancroft Hotel
Address, by President H. J. Ryan
Twenty-Minute Feature

The Industrial Compass, by N. F. Hanley, General Electric Co.

Some Interesting Features of the "Bucking Broncho," by Prof. C. W. Henderson, Syracuse University.

FRIDAY, JUNE 6

10:00 A. M.

TECHNICAL SESSION—LECTURE ROOM, ELECTRICAL ENGINEERING DEPARTMENT, WORCESTER POLYTECHNIC INSTITUTE

The Development of a Suspension-Type Insulator, by Prof. H. B. Smith, Worcester Polytechnic Institute.

Transformers for High-Voltage Testing, by F. B. Cahall, General Electric Co.

An Efficient Tuned Radio-Frequency Amplifier, by Fred Drake and G. H. Browning.

2:00 P. M.

Visit to Worcester Polytechnic Institute Excursion to Industrial Plants.
Recreation
Meeting of Electrical Machinery Committee

8:00 P. M.

TECHNICAL SESSION—LECTURE ROOM, ELECTRICAL ENGINEERING DEPARTMENT, WORCESTER POLYTECHNIC INSTITUTE

Effects of Expansion and Contraction on Insulation of Long Armature Coils, by T. S. Taylor, Westinghouse Electric & Manufacturing Co.

Short Circuits of Alternating-Current Generators, by C. M. Laffoon, Westinghouse Electric & Manufacturing Co.

Torque Pulsations in Single-Phase Motors, by P. L. Alger and A. L. Kimball, General Electric Co.

A. I. E. E. Annual Meeting

The annual business meeting of the A. I. E. E. will be held in the Engineering Societies Building, 33 West 39th Street, New York City, Friday evening, May 16, 1924 at 8:30 o'clock. The results of the annual election of Institute officers will be announced and the report of the Board of Directors for the year ending April 30, will be presented.

At the close of the business meeting, under the auspices of the New York Section, President H. J. Ryan will deliver an address on the subject of "The Atmosphere as a Factor in Electrical Engineering."

Future Section Meetings

New York

The Atmosphere as a Factor in Electrical Engineering, by President Harris J. Ryan. This meeting will be combined with the Annual Business Meeting of the Institute. The announcement of the election of officers of the national body will also be made and it is expected the President-Elect will say a few words. May 16.

Philadelphia

Some Problems of Gas and Electric Utility Management, by James T. Hutchings, Vice-president of the United Gas Improvement Company. May 12.

Vancouver

Annual Meeting for the election of officers. June 6.

Illuminating Engineering Society Meeting, May 8th

The New York Section of the I. E. S. will hold its monthly meeting at the Engineering Societies Bldg., New York City, on Thursday, May 8th, at 8.15 p. m. All members of the Institute are cordially invited to attend.

The meeting will be devoted to a symposium on office lighting. A typical plan of a floor in an office building, including large, medium-size and small offices, has been sent to three members of the Society, who will present their solutions of the lighting problems.

The speakers will be A. B. Oday, Edison Lamp Works; J. E. Blitzer, Lightolier Co.; and H. A. Sinclair, Tucker Electric Construction Co.

Spring Meeting of the A. S. M. E.

The American Society of Mechanical Engineers has planned a most interesting program for its meeting in Cleveland, May 26-29. The great importance of industrial mobilization as insurance against war will be made the keynote of a dinner meeting on May 28th.

W. L. R. Emmet will present a paper on the Mercury-Vapor Process on Wednesday afternoon, which is the first formal presentation by Mr. Emmet of the results of many years' research work.

There will be joint sessions with the American Society for Testing Materials, and the American Society of Refrigerating Engineers on May 29th.

Various committees, including the Committee on Education and Training for the Industries, and the Machine Shop Practise Division, are preparing programs which will be of unusual interest.

A. I. E. E. Spring Convention at Birmingham

An Instructive and Enjoyable Southern Meeting, including Inspection Trips of Unusual Interest

The Spring Convention held in Birmingham, Ala., April 7 to 11 was the first convention of the A. I. E. E. held in the far South and was highly successful in attracting a large delegation of visiting engineers from all parts of the country. Of the total attendance of approximately 350 members and guests, nearly 200 represented various States from New England to California. From both a technical and a social point of view, the Convention was very successful, and the local committee under the energetic and efficient leadership of Mr. W. E. Mitchell is to be congratulated upon the orderly functioning and satisfactory results of its well-laid plans. The weather during the last two days of the convention was the only discordant element in evidence. Rain disorganized the "old fashioned Southern barbecue" for which extensive preparations had been made for Wednesday evening, but a program of typical Southern singing by negro singers was substituted for it and was greatly enjoyed by all present.

A number of ladies was among the convention visitors and thev were provided with some special entertainment in the way of teas, card games and trips, tendered through the courtesy of a local committee of Birmingham ladies. Many of the visiting ladies also took part in the all-day inspection trip to Lock 12 and Mitchell dam on Thursday in spite of the inclement weather.

MONDAY, APRIL 7

The morning was given over to the registration of members and guests and to several committee meetings. The first technical session was called to order in the afternoon at 2:00 o'clock by Chairman Mitchell who called the meeting to order and introduced President McLendon, of the Birmingham City Commission who in a short address welcomed the delegates most heartily to Birmingham.

Chairman Mitchell then took up the technical program and called for the presentation of the following papers in order: *Hydroelectric Practises and Equipment in the South*, by O. G. Thurlow and J. A. Sirnit, presented by Mr. Sirnit. *Developments in Hydroelectric Equipment*, by W. M. White. *Acceptance Tests on Hydroelectric Stations*, by F. H. Rogers. *Hydroelectric Practises and Equipment on the Pacific Coast*, by S. Barfoed presented by J. M. Barry.

An extended discussion followed which related largely to the cavitation of turbine runners and was carried on by Messrs. W. S. Lee, P. M. Downing, George A. Orrok, F. H. Rogers, W. M. White, F. M. Nash, W. F. Dawson and L. F. Harza.

Reception and Dance

On Monday evening a reception and dance was held at the Birmingham Country Club, which was largely attended. Dancing continued until a late hour and was interspersed at intervals with some special interpretive exhibition dances, making a most enjoyable evening.

TUESDAY, APRIL 8

The second technical session convened Tuesday morning, with L. W. W. Morrow, Chairman of the Meetings and Papers Committee presiding. The first paper on *Lightning Arrester Tests* was presented by its author W. F. Young. This was followed in turn by *Lightning Arrester Experiences on the Pacific Coast*, by E. R. Stauffacher. *Lightning Arrester Design and Operation*, by C. E. Bennett. *Operating Experience with Relaying on the Duquesne System*, by H. P. Sleeper and *Economics of Lightning Arresters*, by A. L. Atherton.

The discussion was opened by E. E. F. Creighton followed by K. B. McEachron, G. H. Middlemiss, J. S. Jenks, A. L. Atherton, H. M. Towne, with closure by C. E. Bennett.

Tuesday afternoon session convened with W. E. Mitchell presiding and the first item on the program was an address by Thomas W. Martin, entitled "Southern Power Developments," in which the speaker traced the growth of the electrical power companies of the Southeastern States. The value of interconnection was shown by the fact that 236,000,000 kw-hr. were interchanged in 1923, and Mr. Martin considered that interconnection was the logical outcome of economic laws and the companies involved had sufficient vision to grasp the possibilities of the situation. He also analyzed the conditions and the general situation at the Muscles Shoals development which was formerly owned by the Alabama Power Company and donated to the Government to meet a wartime emergency. He stated that this company was the first to make an offer to purchase the property from the Government and he also compared the offers made by Henry Ford and the power companies.

The next address was by H. M. Addinsell on the "Financial Aspects of Hydroelectric Developments." He stressed the value to the public of the customer ownership of the public utilities and stated that the habit of thrift which this involves benefits both the individuals and the nation by stabilizing business conditions and thus leading to general prosperity.

Following these addresses, the presentation of the technical papers was resumed, the following papers being presented by their authors: *New Type of High-Tension Interconnecting Network*, by Percy H. Thomas and *Carrier Telephony on Power Lines*, by N. H. Slaughter and W. V. Wolfe.

The discussion which followed was participated in by Robert Treat, H. L. Wills, L. F. Fuller, L. P. Ferris, G. Y. Allen, E. B. Craft, W. V. Wolfe, W. S. Lee, H. L. Cole, E. B. Meyer, W. A. Mitchell, H. S. Fitch, F. M. Nash and Percy Thomas.

Evening Session

A meeting of the Institute to which the public was invited was held Tuesday evening at 8.30 p. m. in the auditorium of the John Herbert Philips High School. Mr. T. W. Martin presided and addresses were made by O. C. Merrill, of the Federal Power Commission, P. M. Downing, of the Pacific Gas and Electric Co., and Preston Arkwright, of the Georgia Railway and Power Company. Mr. Merrill spoke of the "National Water Power Development" and called attention to the great hydroelectric development of the Western Coast. He discussed the superpower systems which it is hoped will be eventually interconnected in a nationwide transmission system. "Superpower," he declared, "would provide electric service, would greatly increase the use of the nation's waterpower and the consequent conserving of fuel and reduction of rates." Another aspect of superpower is that it tends to decentralize industry. The federal government now controls about eighty-five per cent of the waterpower resources of the United States and this control is exercised to guard against waste of valuable public resources and to retain ownership in these resources so that they may not be capitalized for speculative purposes.

Mr. Downing spoke on "Best Ways to Use Waterpower for the Benefit of the Public." He pointed out the conditions in California which had been reached through the initiative and foresight of the public utilities companies and told of numerous attempts which had been made to put all the utilities under state ownership. Further attempts, he predicted, would be made in this direction, although the last time the question of state ownership had been defeated by a 3 to 1 vote in this state.

Mr. Arkwright gave an address entitled "Public Relations in Waterpower Development." He discussed the value of amicable public relations in waterpower development, as without public sentiment nothing can succeed and with it, nothing can fail.

Many difficulties have to be met by public utilities in overcoming hostile sentiments and politicians. Among the advantages enjoyed by the users of water power are that they are not affected by strikes, inadequate railroad facilities and other adverse conditions, while at the same time, the rates are comparatively uniform. He also emphasized the fact that in developing waterpower, nothing is used up or destroyed and no property rights are invaded, while on the other hand, service is supervised and the rates are fixed by law, so that the company must necessarily serve everybody without discrimination. He especially emphasized the danger of socializing the industry and making it a political operation.

WEDNESDAY, APRIL 9

The fourth technical session was called to order 9.30 Wednesday morning by Mr. E. B. Meyer, who presided. The subject of this session was "Oil Circuit Breakers" and four papers were presented by the authors as follows: *High-Tension Oil Circuit Breaker Tests*, by H. J. Scholz. *Alabama Power Company Breaker Tests*, by R. W. McNeill. *Investigations of High-Voltage Breakers. Oil Breaker Tests*, by A. J. D. Hilliard and *Oil Breakers from an Operator's Viewpoint*, by J. V. Jenks.

Before opening the discussion, Chairman Meyer called upon Prof. Slichter, who read a telegram from Prof. Harris J. Ryan, regretting his inability to attend the Convention and expressing his best wishes for a successful meeting. After further remarks by Prof. Slichter and Secretary Hutchinson, the discussion of the circuit breaker papers was resumed by Messrs. J. D. Hilliard, J. B. MacNeill, W. E. Mitchell, J. M. Oliver, P. M. Downing, E. E. George, Percy Thomas, G. H. Middlemiss, H. J. Scholz and J. B. Jenks.

The fifth technical session was called to order at 2.30 o'clock on Wednesday, Mr. H. E. Bussey presiding. Four papers were presented by their authors as follows: *New Synchronous Induction Motor*, by Val A. Fynn. *65,000-Kv-a. Generators at Niagara Falls*, by W. J. Foster and A. E. Glass. *Harmonics Due to Slot Openings*, by C. A. M. Weber and F. W. Lee and *22,000-Kv-a. Transformers at Niagara Falls*, by F. F. Brand.

Discussion followed by S. R. Bergman, W. F. Dawson, F. J. Budd, R. B. Williamson (by letter), W. I. Slichter, L. W. W. Morrow, L. P. Ferris, F. S. Dellenbaugh, with closures by Val A. Fynn, W. J. Foster and F. F. Brand.

THURSDAY, APRIL 10

On Thursday morning about 150 of the Convention party boarded the special train at seven o'clock for an inspection trip to Lock 12 and Mitchell Dam of the Alabama Power Company. On account of the early start most of the party took breakfast on the dining car, which accompanied the special train. After a ride of about 50 miles, the party left the train and by means of automobiles made the balance of the trip over slippery country roads to Lock 12. The Lock 12 plant is located on the Coosa River, about 50 miles from Birmingham. The powerhouse in which the large turbines are located forms the entire western portion of the dam, which contains 26 spillway gates, each 30 ft. wide by 14 ft. high. The power house has an area of 323 ft. by 78 ft. and is 160 ft. high. The installation consists of six vertical single runner turbines, direct-connected to 13,500 kv-a. 6600-volt 3-phase Westinghouse generators. After inspecting the Lock and powerhouse for about two hours, the party next proceeded to Mitchell Dam, which is about 12 miles below Lock 12 on the Coosa River.

The plan had been for the party to sail down the river on an open barge, but owing to a steady drizzling rain, the barge party was confined to those who had provided themselves with umbrellas and raincoats, while the remainder of the party returned by automobiles to the special train, which carried them down to Mitchell Dam, arriving about the same time that the barge party landed. A very bountiful luncheon was spread on tables in the powerhouse and disposed of with much satisfaction before the main purposes of the inspection were undertaken. For the balance of the afternoon the party scattered all over the large powerhouse, which they inspected at their leisure, assisted by a number of guides to answer questions and explain details of machinery and operation. Mitchell Dam is 1200 ft. in length, 55 ft. high and 85 ft. wide at the base, and contains 26 spillway gates, each 30 ft. wide by 15 ft. high. The Dam has no powerhouse of the conventional type, each of the generating units being housed in a separate compartment, built on the up-stream side of the Dam. This plant employs the Thurlow backwater suppressor, which prevents the reduction of the operating head during high water. The present installation consists of three 24,000-h. p. Allis-Chalmers vertical single runner turbines, direct-connected to 20,000 kv-a. General Electric 6600-volt generators.

About five o'clock the party returned to Birmingham by train. Dinner was served on board the train and the party reached the Tutwiler Hotel in time to attend the technical session, which was scheduled for 8 o'clock.

The sixth technical session convened at 8.15 o'clock, Mr. F. L. Stone presiding. Four technical papers were presented in abstract by their authors, as follows: *Electrical Safety in Coal Mines*, by L. C. Ilsley. *Automatic Sub-Stations for Mines*, by C. E. Von Sothen. *Tests on Mine Hoist Control*, by F. L. Stone and F. R. Grant and *Automatic Substations for Industrial Plants*, by Chester Lichtenberg.

These papers were discussed by C. A. Butcher, M. J. Lide, W. I. Slichter, G. H. Finks and F. M. Nash, after which some moving picture films were shown, illustrating some of the papers. The meeting then adjourned.

The seventh and last technical session of the Convention came to order at ten o'clock Friday morning, Mr. J. L. Yardley presiding. Four papers were presented in abstract, as follows: *New 20-16 Inch Strip Mill*, by Noble Jones and G. P. Wilson. *Maximum Demand Regulator for Electric Furnaces*, by E. T. Moore. *Manufacture of Phosphoric Acid in Electric Furnaces*, by Theodore Swann and F. V. Andrea and *Effect of Impurities on Battery Electrolyte*, by G. W. Vinal and F. W. Altrup.

These papers were discussed by G. E. Stokes, E. T. Moore, F. M. Nash, L. W. W. Morrow, Theodore Swann, W. E. Mitchell and H. M. Gassman.

Previous to final adjournment the following resolution, presented by Mr. P. H. Thomas, was unanimously adopted:

Resolved, that the Spring Convention of the American Institute of Electrical Engineers extends to the Convention Committee and to its chairman its hearty thanks and grateful appreciation for its exceedingly profitable and enjoyable program, and for the thoughtful provision made for the comfort and entertainment of the members and guests.

Muscle Shoals

Two separate parties in special cars visited Muscle Shoals to inspect the development and power house at the site. The first party left Birmingham Thursday night and the second Friday night. Other members of the party remained in Birmingham over Saturday to inspect various local plants and industries in response to courteous invitations of local industrial and utility companies.

The personnel of the local committee, under whose auspices this most successful convention was held, is as follows: W. A. Mitchell, Chairman, W. J. Baldwin, J. M. Barry, H. E. Bussey, Howard Duryea, H. W. Eales, B. C. Edgar, J. E. Fries, H. M. Gassman, L. W. W. Morrow, A. M. Schoen and F. V. Underwood.

Congress on Distribution Systems to be Held in Paris

Dr. C. O. Mailloux, Honorary President of the I. E. C., and who was also Honorary President of the recent International Conference on High-Tension Electrical Transmission Systems, held in Paris, has received a communication from the French Association of Producers and Distributors of Electric Energy ("Syndicat Professionnel des Producteurs et Distributeurs d'Energie Electrique"), which invites attendance from America at a Convention of the producers and distributors of electrical energy, to be held in Paris, next July, probably after the close of the World Power Conference.

This Convention, or Congress, will have a program that is quite different from the one followed by the High-Tension Conference. Whereas the High-Tension Conference expressly confined its attention to very high tensions, the forthcoming Convention will confine itself to the discussion of systems of medium and low voltages, not exceeding 60,000 volt. Furthermore, the Convention will constitute a gathering of specialists and practical men identified with electrical energy supply-systems, for the purpose of discussing methods of design and operation, and the results obtained in different cases. Manufacturers of electrical machinery and apparatus will be excluded from participation in the work of this Convention, so as to leave the entire time available for the direct work of the Convention. As the Convention will not be, strictly speaking, international, only one language will be used,—the French language. In this way, time will be saved in the discussions, as compared with the case where the same remarks have to be repeated or translated into other languages. This will be a handicap to those whose knowledge of French is limited, but it is hoped that, nevertheless, there will be representatives from all the principal countries in which electricity-supply is an important industry, in order that the exchange of ideas obtained may be as comprehensive and general as possible.

The following are some of the principal subjects that will be considered at the Convention:

- Rates of charge for electrical energy for rural systems;
- Rural installations: use of the ground-return circuit for certain high-voltage lines; three-phase transformers; importance of solidity of construction; advantages and disadvantages of 230 volts, with regard to the ground;
- Protection or safeguards against short-circuits and accidental ground-connections;
- Utilization of electrical energy at night; diversity;
- Means of communication, for high-tension systems;
- Transformer Substations of moderate power; indoor type, semi-outdoor type, and outdoor type;
- Location of defects on transmission and distribution systems of medium voltage;
- Rights of Way for electrical lines on private property:
- Improvement of the power-factor;
- Development of domestic uses of electricity;
- Use of storage batteries for electric vehicles;
- Replacing and preservation of wooden poles;
- Small transformer-stations on poles;
- Limits of capacity of transformer stations; double transformers with automatic switch for service connection;
- Ground return; Bimetallic conductors, etc.

Reports prepared in advance on these and other topics, will be printed and sent to all members of the Congress, to enable them to prepare discussions and communications. Suggestions will be received in regard to other topics that may be deemed of interest. The object is to confine the discussions to matters of as wide and general interest as possible.

Dr. Mailloux will be very glad to hear, as soon as possible, from all who intend to go to this Convention. Its date has been arranged so as to bring it near the time set for the International World Power Conference which is to take place in London. Hence it would be easily possible for anybody to attend both meetings.

John Fritz Medal Presented to Ambrose Swasey

Dr. Ambrose Swasey of Cleveland, O., inventor, manufacturer, philanthropist and dean of the American engineering profession was presented with the John Fritz gold medal, one of the highest distinctions in the world of engineering. The ceremonies took place on the evening of April 23 in the Engineering Societies Build 29 West 39th Street, New York, in the presence of distinguished engineers, scientists and educators from all over the country.

The award was made in recognition of Dr. Swasey's achievements "as a designer and manufacturer of instruments and machines of precision, a builder of great telescopes, a benefactor of education and the founder of Engineering Foundation."

Charles F. Rand of New York, chairman of the Board of Award, presided. Addresses were delivered by General William Crozier, formerly Chief of Ordnance, U. S. Army; Dr. William Wallace Campbell, director of the Lick Observatory and president of the University of California; and John R. Freeman of Providence, R. I., past president of the American Society of Civil Engineers and of the American Society of Mechanical Engineers.

"Four great national societies of civil engineers, mining engineers, mechanical engineers and electrical engineers through their chosen Board of Award unite in this expression of esteem," said Chairman Rand in his address.

"The medal was originally established by these four national engineering societies in honor of a great American metallurgical engineer, John Fritz of Bethlehem, Pa. It has since become an international institution, and is now regarded as the highest engineering honor in America. This is the first time in four years that the medal has been awarded to an American, the last three awards having gone to England, France and Italy.

"A most important and influential undertaking for which Dr. Swasey is responsible is the Engineering Foundation, 'for the furtherance of research in science and engineering or for the advancement in any other manner of the profession of engineering and the good of mankind.' "

General Crozier said that Dr. Swasey throughout his career has been intimately associated with astronomy, adding: "His achievements in that field have carried his name around the world and his accomplishments have been recognized by many universities and foreign governments."

Ambrose Swasey was born at Exeter, New Hampshire, December 19, 1846, of New England lineage. He commenced and completed his schooling in the district school-house. When eighteen years old, he began in Exeter to learn the machinist's trade, which he later followed in Hartford, Conn.

In 1880, with Worcester Reed Warner, he became a manufacturer in Cleveland. Among his numerous inventions is the Swasey range and position finder for artillery. He has built mountings for telescopes in the United States, Canada and South America.

Among his public gifts are the Astronomical Observatory and the chapel at Denison University; the Science Building of the University of Nanking, China; the Christian Association Building of the Canton, China, Christian College; the Pavilion for his native town of Exeter, and the endowment funds for Engineering Foundation.

The John Fritz Medal Board of Award is formed of sixteen men, four representatives from each of the four National Societies of Civil, Mining, Mechanical and Electrical Engineers. The first award was made to John Fritz on his eightieth birthday, August 21, 1902. Other John Fritz medallists have been:

Lord Kelvin, George Westinghouse, Alexander Graham Bell, Thomas A. Edison, Charles T. Porter, Alfred Noble, Sir William H. White, Robert W. Hunt, Prof. John E. Sweet, Dr. James Douglas, Dr. Elihu Thomson, Dr. Henry M. Howe, J. Waldo Smith, General George W. Goethals, Orville Wright, Sir Robert A. Hadfield, Charles Prosper Eugene Schneider, Senator Guglielmo Marconi.

Newly Created Mascart Medal Awarded to André Blondel

A medal of honor called the "Mascart Medal" has been created by the Societé Française des Electriciens to be awarded every three years to a scientist or engineer distinguished for services in the theory and application of electricity. The first presentation of the Medal which was made in February of this year was to André E. Blondel in recognition of his remarkable achievements in electricity and photometry.

This medal was established in December 1923 in remembrance of the eminent French scientist Mascart, who in his lifetime rendered numerous and important contributions to the science of electricity. Eligibility for receiving the medal is not limited by nationality or membership in the Societé but will be governed only by the importance of accomplishments in the electrical arts.

M. Blondel is widely known as an authority among scientists and engineers, and the Societé felt that a highly appropriate way of expressing the prestige of the Medal was by awarding it first to so eminent a person. M. Blondel has been connected with the American Institute of Electrical Engineers since 1905 and was elected an Honorary Member in 1912. He is also Honorary President of the Societé Française des Electriciens and holds many other important offices.

The United States Patent Office as a Field for Life Work

By Karl Fenning, Assistant Commissoner of Patents

The Patent Office is in great need of additional assistance. In recognition of this fact Congress has passed legislation permitting the employment of 100 additional men for a period of two years. The temporary feature of this work should not deter anyone as the national turnover would more than provide for absorption of these additional men.

A good examiner should have enough curiosity to make him want to know the patents and prior publications relating to the particular devices he examines and also those in related subjects in other divisions of the Patent Office. He should have a good enough memory to be able to remember where to find a description he has seen and enough interest in procedure to enable him to acquire a knowledge of principles and decisions in patent law and a ready wit in applying them to the case in hand.

It will be readily seen that the work is extremely interesting. All sorts of things come to the United States Patent Office from the simple darning needle to the complicated steam engine or printing press; from the simple electromagnet to the most complicated system of automatic telephony or wireless transmission of intelligence; from electro-chemical or metallurgical processes to the refining of petroleum or the production of dyes or other chemicals from coal tar. The examiner gets a view and a knowledge of what is new frequently before it is introduced to the general public or even described to technical scientific societies.

Appointments are made in the examining corps from those who pass a technical civil service examination. The entrance salary has been fixed by Congress at $1860, beginning with the 1st of July, 1924, and promotions are made on a strictly merit system up to $5000 a year. The positions are under the civil service and are not political.

Provision is made for retirement with pension in old age. There are over five hundred members of the examining corps and the appropriation bill for next year makes available sufficient funds to put in the corps about one hundred additional examiners.

The civil service entrance examination includes such subjects as are pursued by the scientifically inclined graduate of a college or a technical school. In addition to physics, mathematics, and a reading knowledge of scientific French or German, an examination in the reading of mechanical drawings is required as well as a familiarity with the applied sciences in the field of mechanics, mechanical arts, industrial arts and processes and applied chemistry. Optional engineering examinations may be taken. Examinations are held at many places throughout the United States at short intervals. Complete details of the examinations, as well as the time and place, may be obtained from the United States Civil Service Commission, Washington, D. C.

Examinations are to be held April 9, May 7, June 4, and July 9, 1924. Immediate application should be made to the Civil Service Commission for admission to the examination, and the earliest examination possible should be taken, since those who take an early examination and fail will have an opportunity to take a later examination.

Many new graduates and younger alumni enter the office with the specific idea of training themselves to become patent lawyers. To such persons the universities in Washington offer exceptional opportunities for graduate work in the arts and sciences. Many of the examiners take courses in the law schools connected with the universities in Washington and prepare themselves for the bar.

The work is largely individual and after a few months much personal responsibility rests with the examiner who gains additional experience through frequent conversations with inventors and their attorneys.

There are about a dozen women now in the examining corps and there is no reason why many more college women should not successfully enter the Patent Office as their contribution to public service.

United States Civil Service Examination

The U. S. Civil Service Commission has announced open competitive examinations for engineers and associate engineeers, to fill vacancies in the Bureau of Standards, Department of Commerce. The work includes many branches of physics, chemistry, engineering and technology, and offers valuable experience in connection with original investigations in some field of the Bureau's work.

Full information and application blanks may be obtained from the U. S. Civil Service Commission, Washington, D. C., or from the secretary of the board of U. S. civil-service examiners at the post office or custom house in any city.

Scholarship in Electrical Engineering at Columbia University

The governing bodies of Columbia University have placed at the disposal of the American Institute of Electrical Engineers each year a scholarship in Electrical Engineering in the School of Mines, Engineering and Chemistry of Columbia University. The scholarship pays $350 toward the annual tuition fees which vary from $340 to $360, according to the details of the course selected. Reappointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of a good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements, in regard to which full information will be sent without charge upon application to the Secretary of the University or to the Secretary of the Institute.

In a letter addressed to the Secretary of the Institute, an applicant for this scholarship should set forth his qualifications (age, place of birth, education, reference to any other activities, such as athletics or working way through college, references and photograph). A committee composed of Messrs. Francis Blossom, F. B. Jewett and W. I. Slichter will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for filing of applications for the year 1924-25 will be June 1, 1924.

The course at the Columbia School of Mines, Engineering and Chemistry, is three years in length and is on a graduate basis. A candidate for admission must have had something of a general education, including considerable work in mathematics, physics and chemistry. Three years of preparatory work in a good college or scientific school should be sufficient, if special attention has been given to the three preparatory subjects mentioned. A college graduate, with a Bachelor of Science degree in engineering, can generally qualify to advantage. The candidate is admitted on the basis of his previous collegiate record, and without undergoing special examinations. Other qualifications being equal, members of Student Branches of the A. I. E. E. will be given preference.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that members will show a keen interest in this scholarship, which will insure the choice each year of a candidate of the highest qualifications.

Mathematical Society Seeks Endowment

The American Mathematical Society, an incorporated national organization, has issued an appeal for an endowment of at least $100,000 to continue its scientific activity, as follows:

"Can American engineers afford to let American mathematics decline?

"Mathematics is the basis of those exact sciences on which engineering rests.

"The engineering of the present is based on the mathematics of the past, the engineering of the future will be based on the mathematics of the present and the future.

"Is it not the duty of every engineer to give support to this science which is vital to the welfare of his calling and to the civilization of his country?

"Checks should be made payable to American Mathematical Society Endowment Fund, and sent to the Society's office, 501 West 116th Street, New York City."

EMF Electrical Year Book

The EMF Electrical Year Book for 1924, which has just been received, contains several innovations. Chief among these is a geographic section, which gives branch offices, special agents and local or district jobbers of the advertisers. These are arranged by states and cities.

Special attention has been given to radio topics and important additions have been made on the subjects of automatic substations and generating stations, electric automobiles and trucks, wiring systems of gasoline automobiles, electrical inspection and public utility commissions.

Several hundred illustrations have been added, which aim to make the text clearer and more interesting and also several tables of data that will be most useful.

Lehigh Valley Section Holds Extended Meeting

A whole-hearted manner of doing things is a characteristic of the Lehigh Valley Section which was emphasized by the meeting held on April 11 and 12 at Wilkes-Barre, Pa. This Section convention started with dinner on Friday evening, which was followed by three interesting papers and on Saturday inspection trips were made to two manufacturing plants. The meeting was one of the most enthusiastic ever held by this Section.

At the very enjoyable dinner preceding the meeting and held at the Readington Hotel about 90 covers were spread. The dinner was enlivened by appropriate music under the direction of Mr. David Morgan, sales engineer of the Hazard Manufacturing Company, who also led singing at appropriate times during the evening meeting.

There was one paper on "Electric Cables" presented by Carl P. Brodhun, Assistant General Sales Manager of the Hazard Manufacturing Company; and another on "Wire Rope—Its History and Use" by Lawrence W. Bevan, Assistant General Manager of the same company. The third paper was on the "History and Manufacture of Incandescent Lamps" by Henry Schroeder, Sales Manager of the Edison Lamp Works, Harrison, N. J. Following this paper, moving pictures illustrating the processes of lamp manufacture were shown.

After the papers a short talk was given by R. B. Mateer, Chairman of the Philadelphia Section, and Irving Samuels talked on the advantages to be gained through membership in the Institute. The Secretary then read a letter from L. C. Brooks, organizer and first chairman of the Lehigh Valley Section.

The inspection trips made on the next day gave a further insight into the subjects covered in the papers. The first trip was through the plant of the Hazard Manufacturing Company at Wilkes-Barre. After this inspection luncheon was served at the plant. From there the party went to Scranton and were shown through the factory of the Edison Lamp Works. About 70 members and guests enjoyed these trips.

Another interesting meeting is promised by this Section for May 8 at Allentown, Pa. This meeting also will be preceded by a dinner after which there will be papers on "Supervisory Control of Power Systems" by representatives of the General Electric Company and the Westinghouse Electric and Manufacturing Company. Demonstrations of apparatus will add to the interest of the meeting.

Addresses Wanted

A list of names of members whose mail has been returned by the Postal Authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnecessary expense for postage and clerical work.

1.—J. T. Brown, 522 32nd St., Oakland, Calif.
2.—John P. Byron, c/o Waldorf Hotel, Seattle, Wash.
3.—B. L. Cathey, 736 Ross Ave., Wilkinsburg, Pa.
4.—D. S. Dewire, 39 6th Ave., La Grange, Ill.
5.—W. J. Gibbons, Toko St., Rotorua, N. Z.
6.—Frank W. Griffin, Sorgel Elec. Co., 138 W. Water St., Milwaukee, Wis.
7.—Jerome S. Haas, 2011 Atlantic Ave., Atlantic City, N. J.
8.—W. A. Harding, Camp 60, Big Creek, Calif.
9.—J. A. Hooper, 195 E. 47th St., Portland, Ore.
10.—Tadashi Iida, Architectural Dept., So. Manchuria Rwy. Co., Dairen, Manchuria
11.—Herbert A. Kellar, Colorado Power Co., Glenwood Springs, Colo.
12.—Albert L. Luther, 9341 Moffat St., Detroit, Mich.
13.—Orrin MacMurray, c/o Crocker-Wheeler Co., Ampere, N. J.
14.—S. F. Nelson, 57½ So. Pryor St., Atlanta, Ga.
15.—Henry C. Schnake, 21 E. 40th St., New York, N. Y.
16.—Alfred O. Tate, c/o Tate Laboratories, Cranston, R. I.
17.—W. J. Timmins, 1219 11th St., Des Moines, Iowa.

American Engineering Council

ANNOUNCEMENT OF PERSONNEL OF COMMITTEES AND FUTURE ACTIVITIES

Chief among the tasks of the Council for the year will be the prosecution of a country-wide campaign to conserve the forest reserves of the nation. It plans to work with federal, state and other agencies in devising plans to overcome the dwindling of the nation's forests.

Efforts will also be made to reorganize the Department of the Interior.

The Council opposes vigorously the plan of the U. S. Joint Committee on Reorganization to leave river and harbor work and the Mississippi River Commission, now under the corps of engineers out of the Public Works Division.

The chairmen of the various committees are as follows:

J. C. Ralston of Spokane, Wash., Committee of Reforestation and Timber Supply.

Gardner S. Williams of Ann Arbor, Mich., Committee on Government Reorganization as Related to Engineering Matters.

Calvert Townley of New York, Public Affairs Committee.

Dean Arthur M. Green, Jr., of Princeton University, Committee on War Dept. Personnel.

F. K. Copeland of Chicago, Committee on Elimination of Waste in Industry.

William McClellan formerly of the University of Pennsylvania, Federal Power Committee.

E. J. Prindle of New York, Committee on Patents.

Max Toltz of St. Paul, Committee on Contracts and Adjustments.

Calvert Townley and Fred R. Low of New York and John H. Finney of Washington have been appointed delegates to the World Power Conference in London. W. R. Ingalls of New York is the Council's representative on the National Bureau of Economic Research. Rudolph P. Miller, also of New York, was reappointed to the National Board for Jurisdictional Awards.

THE TEMPLE BILL

The A. E. C. has placed before President Coolidge a resolution adopted by its Administrative Board favoring the Temple measure, which provides for the complete topographic mapping of the United States.

Ex-Governor James Hartness of Vermont, speaking for the Council, said in part "To aid in the intelligent building-up of our transportation system, in the development of super-power plants, in the extension of irrigation and drainage projects, an accurate knowledge of the configuration of the earth is essential." After enumerating the advantages that such information would be to every line of industry, to the public in general and in the saving of expense, he concluded by saying that such an appropriation which Congress would have to supply for this purpose should not be looked upon as an item of current expense, but as an increase in the Nation's capital stock, and would pay back into our national treasury amounts far exceeding the outlay.

COMMITTEE APPOINTED TO REPORT ON MUSCLE SHOALS DEVELOPMENT

A committee has been appointed by the A. E. C. to study the Muscle Shoals situation for the U. S. Senate Committee on Agriculture and Forrestry.

The personnel of the engineering committee consists of: F. R. Low, president A. S. M. E. and Dr. Leonard Waldo both of New York, Dr. H. E. Howe, Washington, E. B. Whitman, Baltimore, J. B. Davidson, Ames, Iowa, Prof. H. B. Walker, Kansas State Agricultural College and Harold Buck of New York, a member of the A. I. E. E.

After the committee has made its report, some of the members will be requested to appear before the Senate Committee for questioning.

PERSONAL MENTION

Bernhard F. J. Day has joined the staff of A. E. Fitkin & Co., 209 Van Nuys Bldg., Los Angeles, Calif.

C. A. Larson was transferred from the Public Service Co. of Colorado to the St. Joseph Heat, Rwy., Light & Power Co., St. Joseph, Mo.

J. Lane Polk, Jr. has accepted the position of Assistant Transmission Line Engineer with the Pennsylvania Power and Light Company, Allentown, Pa.

Roy S. Redmon, formerly Chief Draftsman for the Union Gas & Electric Co., is now connected with Stone and Webster, 80 Broad St., Boston, Mass.

Hugh A. Brown, having resigned as Sales Manager of the Electro Dynamic Company, is now connected with the Otis Elevator Company of New York City.

Louis G. Bischoff has severed his connections with the Bell Telephone System and on March 1st began work with the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

W. A. Oehlschlager has become associated with the Union Switch & Signal Company, Swissvale, Pa., having severed his connections with the Pennsylvania Railroad System.

Alexander A. Leeven is now Electrical Designer of the Electrical Bond and Share Co., 73 Broadway, New York City. Mr. Leeven was formerly with the New York Edison Co.

F. A. Mulvany has resigned his position with the Pacific States Electric Company to accept the position of Sales Manager with the Electric Sales Service Company, Berkeley, Calif.

Frank Casper Wagner, former Professor of Electrical and Mechanical Engineering at the Rose Polytechnic Institute, is succeeding Prof. P. B. Woodworth as President of that institution.

Allen E. Ransom is now Electrical Engineer with the American Foreign Power & Light Co., Guatamala City, Guatamala, Cen. Am. Mr. Ransom was formerly with E. B. Hussey, Seattle, Wash.

Norman M. Albert has left the General Electric Company of Schenectady, N. Y. and is now Research Engineer, Bureau of Tests and Inspections of the Pacific Gas & Electric Co., San Francisco, Cal.

Henry Harseim, former President of the Eastern Electric Construction Co., Ltd., has been elected Vice-president of the Causbey Engineering Company, Inc., Bankers Trust Bldg., Philadelphia, Pa.

R. H. Soper has severed his connections with the Central Cespedes, Camaguey, Cuba, and has resumed his former occupation as Turbo Erecting Engineer, General Electric Company, West Lynn, Mass.

Julian Loebenstein has severed his connection with the Hopewell Insulation & Mfg. Co. and has joined R. Roth in the sale of high-tension switching, protective and distribution equipment, 30 Church St., New York City.

Earl A. Keeler has resigned his position as Research Manager of the Brown Instrument Co. to engage in research and engineering work as a personal undertaking. His present address is 6517 North 9th St., Philadelphia, Pa.

Guy W. Thaxton resigned his position as Assistant Professor of Electrical Engineering at the Georgia School of Technology to become associated with the Central Station Division of the Westinghouse Electric & Mfg. Co., Atlanta, Ga.

Elmer Schneider has taken a position with the Republic Flow Meters Co., Chicago, Ill. as head of the laboratory of the pyrometer section. The company has just begun the manufacture of this article and it will be on a production basis by early fall.

John Hood, for several years Engineer of the General Electric Company, San Francisco, and for the past three years Assistant Manager of Catton-Neill & Co., Ltd., Honolulu, T. H., has been appointed Manager of the Oakland Works of the General Electric Company.

B. C. Thayer has been appointed Asst. Power Plant Supt. of the Connecticut Light & Power Co. with headquarters at the 200,000-h. p. steam plant now being erected at Devon, Conn. For the past twelve years Mr. Thayer had been with the Westinghouse Electric & Mfg. Co.

Frederick Bedell, Professor of Applied Electricity at Cornell University and past Vice-president of the Institute, recently made a 12,000-mile motor camping trip around the rim of the United States. The trip is described by Mrs. Bedell in a book entitled "Modern Gypsies," just published by Brentano's.

H. E. Dalzell has been appointed Chief Mechanical Engineer and Electrical Adviser to the San Paulo Railway Co., San Paulo, Brazil. Since his resignation from the Southern Rys. of Peru in 1922, Mr. Dalzell had been engaged by the La Guaira & Caracas Rly. as Consulting Engineer for the electrification of their railway in Venezuela.

G. A. Sawin, Assistant to Manager, Supply Sales Department, Westinghouse Electric and Mfg. Co., has been elected chairman of a new section of the Electric Power Club. The section, including instruments and instrument transformers, was recently organized. Mr. Sawin, who is chairman of the Instruments and Measurements Committee, has also been appointed chairman of a committee for revising the Institute's standards, pertaining to instrument transformers.

Robert L. Eltringham, for the past three years Manager of the California Electrical Cooperative Campaign, was appointed Assistant to the Managing Director of the National Electric Light Association, New York City on January 1st. Mr. Eltringham for several years was Electrical Engineer of the California Industrial Accident Commission, during which time he assisted in the formulation of the National Electric Safety Code with the United States Bureau of Standards and introduced the plan of combining codes for fire and accident prevention.

Philip B. Woodworth after 37 years of collegiate work has formed a partnership with the law firm of Rummler & Rummler under the firm name of Rummler, Rummler & Philip B. Woodworth, 7 South Dearborn St., Chicago, Ill. For the past three years Prof. Woodworth was President of the Rose Polytechnic Institute, Terre Haute, Ind., where he assumed responsibility for the construction of a complete new engineering college plant, He was admitted to the bar of the Supreme Court of Indiana in October, 1923.

M. E. Skinner, Assistant to the Vice-President of the Duquesne Light Company, Pittsburgh, has been appointed manager of the recently created commercial department of that company. Prior to entering the service of the Duquesne Co. in 1922, Mr. Skinner spent six years in the transformer design department of the Westinghouse Elec. & Mfg. Co. He is a graduate of the University of Wisconsin, has been very active in Institute affairs and is now the Chairman of the Membership Committee and Secretary of the Pittsburgh Section.

J. G. Pearce, who has been associated for some years with A. P. M. Fleming in the development of the Research Department of the Metropolitan-Vickers Electrical Co., Ltd., Manchester, England, has been appointed Director of the British Cast Iron Research Association. Mr. Pearce is joint author with Mr. Fleming of "Research in Industry," published in 1922 by Pitman and made many friends in this country during his visit for seven months last year, being located for most of this time at the East Pittsburgh plant of the Westinghouse Electric & Mfg. Co.

Obituary

Charles Wirt, an inventor of many well-known electric lighting appliances, died on April 13th at his home in Philadelphia, at the age of sixty-six.

For many years, Mr. Wirt was associated with Thomas A. Edison, in experimental work at the laboratory in Orange, N. J. and held positions in various Edison Companies. Later he organized a company under his own name, for manufacturing electrical devices, among which are the Wirt rheostats, dielite insulating joint, portable voltmeter and potentiometer.

In 1900, Mr. Wirt received the John Scott Medal from the Franklin Institute, of which he later became a member. He became a Fellow of the A. I. E. E. in 1914.

Robert Francis Hayward, for many years a prominent central-station engineer and manager who took an active part in affairs of the Institute, died in London, England, early in April. Mr. Hayward was widely known among engineers and executives through his work with the Salt Lake and Odgen Gas and Electric Company as manager, 1894-97; with the Union Light and Power Company, Salt Lake City, as electrical engineer, 1897-99; with the Utah Light and Power Company, Salt Lake City, as chief engineer, 1899-1905, and after four years, 1905-09, in Mexico City with the Mexican Light and Power Company, with the Western Canada Power Company, Vancouver, B. C., as general manager, where he remained until 1920.

In 1920 Mr. Hayward was appointed general manager of the Chilean Electric Tramway and Light Co., Ltd., Santiago, Chile.

Born in 1865 at Harrow, England, Mr. Hayward was educated at Harrow School and University College, London, and was later connected with Crompton and Company, Chelmsford, where he was made superintendent of shops. From this company he came in 1894 to America.

He was an enthusiastic supporter of the Institute and was active in organizing the Vancouver Section in 1911. He became an Associate of the Institute in 1903, in 1907 was transferred to the grade of Member and in 1912 to the grade of Fellow.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 6 p. m.

BOOK NOTICES MARCH 1-31, 1924

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made; these are taken from the preface or the text of the book.

All the books listed may be consulted in the Engineering Societies Library.

Electric Arc and Oxy-Acetylene Welding.

By E. Arthur Atkins. Lond., & N. Y., Isaac Pitman & Sons, 1923. 316 pp., illus., diagrs., tables, 7 x 5 in., cloth. $2.50.

A very complete manual on methods, equipment and materials, and on the welding of various metals. Gives the results of many tests and experiments.

Electro-Chemistry Related to Engineering.

By W. R. Cooper. N. Y., D. Van Nostrand Co., 1923. 136 pp., illus., diagrs., 9 x 6 in., cloth. $3.75.

Brings together, for convenience, the scattered information on a number of electrochemical problems and methods that are essentially of interest to the engineer and presents them in a way that emphasizes certain underlying principles. The questions discussed are: Electrolytic corrosion by stray earth currents; The effect of superimposing alternating currents on direct currents; The corrosion of brass; Electric osmosis and cataphoresis; The electrical precipitation of dust, smoke and fume; Electroculture; The relative importance of cheap power and cheap freights.

Die Elektrostahlofen.

By E. Fr. Russ. München u. Berlin, R. Oldenbourg, 1924. 471 pp., illus., diagrs., 10 x 6 in., paper. $3.30.

This volume on the electric steel furnace is intended to give the steel maker a thorough practical account of the use of the electric current for melting steel. It therefore assumes no technical knowledge of electrical engineering on the part of the reader, theoretical points are discussed as briefly as possible and attention is concentrated on the practical questions and requirements which directly interest the metallurgist.

The book commences with a statement of basic electrical principles, which is followed by a discussion of the various methods of heating by electricity. The various types of furnaces that have been tested in practise are then described and their advantages explained. The concluding section treats of the parts of furnaces; electrodes, regulating and safety apparatus, measuring devices, etc.

Gasworks Recorders, Their Construction and Uses.

By Leonard A. Levy. Lond., Benn Brothers; N. Y., D. Van Nostrand Co., 1922. 246 pp., illus., diagrs., 10 x 7 in., cloth. $10.00.

Describes the pressure recorders, vacuum gages, pyrometers, specific gravity apparatus, calorimeters, gas analysers, volume recorders, densimeters and depth gages used in gas works, and explains their use and maintenance. Intended for students as well as for engineers.

Hendricks Commercial Register of the United States.

32d annual edition. 1924. N. Y., S. E. Hendricks Co., 1923. 2402 pp., 12 x 8 in., cloth. $15.00.

A very full directory of manufacturers and dealers, compiled with special reference to the requirements of those engaged in engineering, mining, railroading, building and kindred industries. The commodities are listed under some 17,000 headings. An index of trade names and an alphabetical list of firms are included.

Life of Sir William Crookes.

By E. E. Fournier D'Albe. N. Y., D. Appleton & Co., 1924. 413 pp., port., 9 x 6 in., cloth. $7.50.

Sir William Crookes led a long life of activity in many lines. He was an early expert in photography, he founded the *Chemical News* and edited it until his death, he discovered thallium and invented the radiometer. He was an early scientific investigator of spiritualism. His technical activities were many and varied.

His biographer presents an interesting life of the man as his friends knew him, largely through extracts from his letters and other writings.

Low Temperature Carbonization.

By S. N. Wellington and W. R. Cooper. Lond., Charles Griffin & Co.; Phila., J. B. Lippincott Co., 1924. 238 pp., diagrs., tables, 9 x 6 in., cloth. $9.50.

While much has been written in periodicals on this subject, the authors of this work feel that it has not hitherto been treated adequately in book form. The present volume discusses theoretical aspects of the problem, describes the systems that have been tried commercially and presents unpublished results of research. The volume concludes with a consideration of the power aspects of low-temperature carbonization. An appendix gives abstracts of the important British patents.

Measurement of Steady and Fluctuating Temperatures.

By R. Royds. N. Y., D. Van Nostrand Co., 1921. 162 pp., illus., diagrs., 9 x 6 in., cloth. $4.00.

This book gives a concise account of modern methods for measuring both steady and fluctuating temperatures and indicates their applications in industry. Mercury thermometers, electrical thermometers and pyrometers, radiation and optical pyrometers and other types are described. There are chapters on calibration, on the measurement of the mean temperature of thin metal walls, such as engine cylinder walls and boiler tubes, and on the measurement of rapidly fluctuating temperatures.

Planned Control in Manufacturing.

By William O. Lichtner. N. Y., Ronald Press Co., 1924. 329 pp., 9 x 6 in., cloth. $5.00.

This volume sets forth the basic principles of planned control which are applicable to any business and which make it possible to obtain the full benefit of standardization through job analysis. The author has not treated the subject exhaustively but has discussed intensively the points that experience has shown to be of primary importance. The book treats of the installation and maintenance of control methods and the selection and

training of the control staff, describes the relation of these methods to purchasing and cost accounting, and applies planned control in detail to a small plant, as a practical example.

THEORIE GENERALE SUR LES COURANTS ALTERNATIFS, Pt. 1.

By M. E. Piernet. Paris, Gauthier-Villars et Cie., 1924 100 pp., 10 x 6 in., paper. 12 fr.

The first portion of a treatise which will comprise a complete study, limited to fundamental ideas and technical practise, of alternating currents and alternating-current machinery. The present work deals with the general theory of alternating currents and includes sinusoidal, polyphase and non-sinusoidal currents, the use of imaginary quantities and the theory of rotating fields.

THOMAS' REGISTER OF AMERICAN MANUFACTURERS. 1923-24.

N. Y., Thomas Publishing Co., 1924. 4300 pp., 12 x 9 in., cloth. $15.00.

Little change in general character is to be expected in a directory that has gone through fourteen editions, and the new edition of "Thomas" follows the lines of preceding ones. It is, however, enlarged by over a hundred pages.

The Register lists and indexes manufacturers and first hands in all lines, making it easy to locate sources of supply for any commodity. An alphabetical list of forms, an index to trade names and brands, a directory of banks, boards of trade and other organizations, and a directory of trade papers are also included. Capital ratings are given for all firms. It is, the publishers claim, the largest directory for buyers.

WEALTH AND INCOME OF THE AMERICAN PEOPLE.

By Walter R. Ingalls. 2d edition. York, Pa., G. H. Merlin Co., 1923. 372 pp., tables, 9 x 6 in., cloth. $3.50.

In the present book Dr. Ingalls aims to explain the nature of the wealth of the United States and to examine comparatively the positions before and after the war. He discusses the amount of the income that we as a people derive from the use of our wealth and our work and the distribution that we make thereof; and finally he discusses the economic consequences of the war to us and the way in which the ravages of the war may be repaired.

In the new edition corrections have been made, some later data added to the tables and three new chapters have been added.

COLLOID CHEMISTRY.

By The Svedberg. N. Y., Chemical Catalog Co., 1924. (American Chemical Society. Monograph series). 265 pp., illus., diagrs., tables, 9 x 6 in., cloth. $3.00.

A general survey of colloid chemistry in which special attention is accorded to recent developments in technique and emphasis is placed on quantitative investigations. The book is based on a series of lectures delivered at the University of Wisconsin. A bibliography is included.

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Travelogue on South America, by Calvin W. Rice, Secretary, A. S. M. E. Joint meeting with A. S. M. E. This talk was one of general as well as engineering interest, and was profusely illustrated by hand-colored lantern views and moving pictures. March 21. Attendance 275.

Boston

Corona Investigations on an Artificial Line, by Murray F. Gardner. F. S. Dellenbaugh prefaced the paper with a general statement of the investigations and why it was undertaken. March 4. Attendance 55.

Machine Switching, by Edward M. Surprise, New England Telephone and Telegraph Company. The speaker gave a very comprehensive talk on this subject, illustrating it with lantern slides. March 27. Attendance 60.

Cleveland

Education and Development of Men for the Industry, by Paul M. Lincoln, Cornell University. The speaker gave a summary of the present state of the problem and some very interesting statistics. March 20. Attendance 45.

Connecticut

Building the Financial Structure of a Public Utility, by Samuel Ferguson, President of the Hartford Electric Light Co. Chairman Everit briefly touched upon the significance to the public of the problem of Public Utility financing. Discussion followed Mr. Ferguson's talk. T. H. Soren, Vice-President of the Company, told of some experiences with the mercury turbine which had been operating at the Dutch Point Plant since September. March 27. Attendance 200.

Denver

Temperature Measurements and Their Relation to Electrical Apparatus, by D. J. McQuaid, Western Representative of the Taylor Instrument Companies. The speaker gave a most interesting and instructive talk, bringing out many important points relative to temperature measurements and the construction of thermometers, which require much exacting research and development work to produce accurate results. March 21. Attendance 14.

Detroit-Ann Arbor

What the Telephone Transmits, and How You Hear It, by John Mills, Personnel Director, Western Electric Co. Animated moving pictures were used to illustrate how sound waves produce electrical waves in a telephone circuit and how these electrical waves are detected and converted back to sound waves. Mr. Mills told something of the work of the Bell system Laboratories on the characteristics of human speech and audition. March 13. Attendance 200.

Erie

The Effect of Power Factor and Its Correction on Electric Power Bills, by James Burke, President, Burke Electric Co. The lecture was illustrated with lantern slides which were of special interest to induction motor users and purchasers of large blocks of power. An informal smoker and discussion followed, during which the synchronous induction motor was explained. March 18. Attendance 200.

Indianapolis-Lafayette

A Newly Developed Vibration Recorder and Its Applications, by Chester I. Hall, General Electric Co. The application of Mr. Hall's vibration recorder was surprising to those who heard him. Vibrations or tremors of the end of the finger held freely at arms length can be recorded with great accuracy. March 27. Attendance 25.

Lehigh Valley

Electric Cables, by Carl P. Brodhun, Assistant General Sales Manager, Hazard Manufacturing Company.

Wire Rope—Its History and Use, by Lawrence W. Bevan, Assistant General Manager.

History and Manufacture of Electrical Lamps, by Henry Schroeder, Sales Manager, Edison Lamp Works, Harrison, N. J.

Inspection trips to Hazard Manufacturing Company and Edison Lamp Works, Scranton, Pa. The meeting including the above papers and trips was held on April 11 and 12. Fuller details are given on page 475. Attendance April 11, 90; April 12, 70.

Los Angeles

The Measurement of Surges in Power Systems, by E. W. Copley, Westinghouse Electric & Manufacturing Co. Mr. Copley described in a most interesting manner the development within the last few months, by Mr. Peters of the Westinghouse Company, of the klydonograph, by means of which a photographic record is produced on a plate. The lecture was illustrated with lantern slides. March 3. Attendance 75.

Lynn

The Theory of Rectifier Operation, by R. D. Amsden.

Considerations Involved in Establishing the Rating of a Polyphase Induction Motor, by D. Lee Chesnut.

A Method of Determining the Definition of Motion Picture Projection Lenses, by L. Olson. These papers were illustrated by blackboard diagrams and lantern slides and discussion followed. March 19. Attendance 80.

Thirteenth Annual Banquet at Boston City Club. The speakers of the evening were Toastmaster Leon E. Smith, F. P. Cox, N. J. Darling, G. Faccioli and Captain Irving O'Hay. March 29. Attendance 280.

Madison

The Design and Operation of the Fynn-Weichsel Motor, by H. N. Felton, Wagner Electric Corporation. March 12. Attendance 35.

New York

The Telephone System of Greater New York, by G. W. McRae, Chief Engineer, New York Telephone Company. Mr. McRae reviewed the development of the telephone system for a period of about 20 years. He outlined the problems which have confronted the company's engineers due to the phenomenal growth of the city and touched upon plans already laid to meet conditions predicted up to 1940 and 1960. Moving pictures preceded the paper and the talk was freely illustrated with slides. Discussion was participated in by H. C. Carpenter and other engineers and officers of the New York Telephone Company. Chairman Morehouse opened the meeting with an announcement of the election of officers for the year 1924-25, as follows: H. H. Barnes, Chairman, General Electric Company, R. H. Tapscott, Secretary-Treasurer, New York Edison Company, W. S. Gorsuch, Interborough Rapid Transit, and E. B. Meyer, Public Service Electric Co. of New Jersey. April 16. Attendance 515.

Oklahoma

Modern Tendencies in Engineering Education, by Professor Tappan, Oklahoma University.

Early Days of the Central-Station Industry, by Mr. Knox.

Muscle Shoals Development, by W. J. Canada.

Electrical Troubles on the Distributing System, by W. K. Danvers, Oklahoma Railway Company.

The New Oklahoma Gas and Electric Company Plant at Muskogee, by Mr. Hunter, Oklahoma Gas and Electric Company. March 11. Attendance 18.

Philadelphia

Stability of Transmission Lines, by R. D. Evans, Westinghouse Electric and Manufacturing Company. This paper which dealt largely with derivation of formulas to determine conditions of stability was listened to with a great deal of attention.

The Klydonograph, by J. L. E. Peters, Westinghouse Electric and Manufacturing Company. This paper described a device for photographically recording surges on transmission and distribution lines. By means of the device disturbances lasting twenty billionths of a second are said to be recorded. The apparatus makes use of an ordinary photographic plate so connected electrically that the electrical variations are brought into contact with the sensitized surface. It was pointed out that the impressions recorded on the plate take on certain definite forms which indicate the character of the impulse showing whether the voltage is alternating on uni-directional, positive or negative, and its intensity and direction of travel. March 10. Attendance 130.

Pittsburgh

High-Voltage Sub-Stations, by G. S. Humphrey, West Penn Power Company. The speaker outlined the economics of high-tension substation design and the details of the new Charleroi Substation of the West Penn Power Company. March 11. Attendance 161.

The Klydonograph, by W. L. Teague, Westinghouse Elec. & Mfg. Co. This paper described in a very interesting way a new device for graphically recording surges on transmission systems. A lively discussion followed. April 8. Attendance 170.

Pittsfield

The SCR Single-Phase Repulsion Induction Motor, by S. R. Bergman and H. R. West of the General Electric Company. Mr. Bergman gave an interesting discussion of the history of the development of the single-phase motors. Mr. West discussed the theory of the new motor, outlining the methods of determining its equations. March 13. Attendance 200.

Riding on Air, by G. M. Powell, Firestone Tire & Rubber Company. The speaker discussed the history of rubber, going back to the earliest records of its use and leading up to the present-day use in automobile tires. March 20. Attendance 175.

Portland

A lecture was given by L. A. McArthur, Vice-President and General Manager, Pacific Power and Light Company, who presented views of recent construction work and a film used in their "Road Show." He explained how the film and lecture are used to inform their customers about the company and its business. Discussion followed and refreshments were served. Joint meeting with N. E. L. A. December 19. Attendance 85.

Telephone Communication and Audition, by George B. Thomas, Western Electric Company. The paper was illustrated with several reels. Refreshments were served. Joint meeting with N. E. L. A. January 23. Attendance 85.

Illumination and Some Modern Ideas in Residence Lighting, by Mr. Rademacher, Harrison Lamp Works of General Electric Company. Joint meeting with N. E. L. A. Ladies' Night. Dancing followed. February 20. Attendance 200.

An Atom and What's Inside of It, by Professor A. A. Knowlton of Reed College. Several simple experiments were performed and a film "Beyond the Microscope" was shown. R. R. Robley of the Portland Railway, Light & Power Company gave a short account of the life and activities within the Schenectady Works of the General Electric Company. Joint meeting with N. E. L. A. Refreshments were served. March 12. Attendance 60.

The Development of the Super-Heterodyne, by Ellery Stone of the Pacific States Electric Company. The lecture was accompanied by a film, entitled "The Wizardy of Wireless." A buffet lunch was provided at the close of the discussion. Joint meeting with N. E. L. A. April 9. Attendance 150.

Rochester

Recent Developments in Steam Power Plants—Effect of High Steam Pressures and Superheat, by Eskil Berg, General Electric Company. Joint meeting with Rochester Engineering Society. March 14. Attendance 125.

St. Louis

Design and Construction of Cahokia Station, by H. W. Eales, Union Electric Light & Power Company. The speaker gave a very interesting description of the construction of this power station and his talk was accompanied by slides. Discussion followed. March 27. Attendance 81.

Schenectady

Electrical Possibilities in South America, by S. B. Fortenbaugh. The speaker told many interesting stories of his experiences in South America, accompanying his talk with slides indicating the customs and peculiarities of the people of South America. Motion pictures were shown dealing with construction of the Paulista Railway. March 7. Attendance 120.

Brightness and Color in Illumination, by Bassett Jones. The lecture dealt with some interesting problems in artificial illumination as applied to office and factory lighting, and the decorative effect of proper illumination in flood lighting. March 21. Attendance 280.

Something about Bearings, by E. G. Gilson. The talk dealt with some recent experiments made on machine bearings. An interesting discussion followed. April 4. Attendance 76.

Seattle

The Oak Grove Development of the Portland Railway Light & Power Company, by B. W. Proebstel. The talk was accompanied by slides and films, setting forth the progress made in the art of transportation from the days when the Indian controlled the northwest region to the present day. Discussion followed. March 20. Attendance 90.

Southern Virginia

John C. Hoyt of the Bureau of Geological Survey of the Federal Department of Interior gave a lecture on the survey of the Colorado River. It was illustrated with slides and moving pictures.

Geo. W. Robertson, General Superintendent of the Dan River Cotton Mills at Danville, Va., gave a general description of the manufacture of cotton cloth as practised in his mills, and also gave an interesting account of the co-operative system of labor management as practiced there.

G. B. Nichols, a Consulting Engineer, spoke on industrial heating with particular reference to the heating of a large number of isolated buildings from a central boiler plant.

R. R. Taliaferro, of the Carrier Engineering Company, described apparatus for conditioning air in cotton mills and tobacco factories.

Hon. Fred Harper, Mayor of Lynchburg, spoke of the interest that all engineers should take in municipal engineering.

Allen J. Saville, Director of Public Works, Richmond, Va., gave a talk on location of industrial plants in regard to balance of community.

Dr. Thorton, Dean of Engineering at the University of Virginia, spoke of the law licensing engineers that is now on the statute book of Virginia and felt very confident that such a law would be beneficial to the engineering profession. At the close of his talk he presented C. G. Massie of Lynchburg with a gold watch on behalf of the engineers of the State of Virginia. All day meeting, joint with the A. S. M. E. and A. S. C. E. March 28. Attendance 50.

Springfield

High-Tension Ignition, by L. F. Curtis, American Bosch Magneto Corporation. Discussion followed. March 31. Attendance 69.

Toledo

A demonstration of a super-heterodyne receiving set was made. March 20. Attendance 55.

Toronto

E. M. Watts of the Ward Electric Company gave a talk on the advantages of using electric trucks for city deliveries. March 14. Attendance 40.

Transmission-Line Phenomena, by J. F. Peters, Westinghouse Elec. & Mfg. Co. The speaker dwelt particularly on the development of the "klydonograph." Discussion followed. Refreshments were served. Joint meeting with the Hamilton Branch of the Engineering Institute of Canada. March 28. Attendance 250.

Utah

High-Tension Transmission, by William A. Hillebrand, Ohio Brass Company. The speaker presented a very able discussion of the latest practises in transmission at high potentials. The paper was illustrated by lantern slides, showing various methods of construction used in different parts of the country. Discussion followed. February 21. Attendance 60.

Vancouver

Development of the Bridge River Project, by J. R. Read. The paper, which was illustrated by fifteen slides, gave a general description of the various features of a water-power project on the Bridge River in British Columbia. April 4. Attendance 39.

Washington

Gearing Radio's Time Element to Man's Needs, by Capt. R. H. Ranger, Radio Corporation of America. This paper dealt with possibilities of the use of radio in other and more important fields than that of broadcasting entertainment. Capt. Ranger also performed several experiments. March 11. Attendance 340.

Great Falls of the Potomac as a Power Development, by Francis R. Weller. Noon-day luncheon meeting. March 25. Attendance 43.

Railway Electrification as a Matter of Operating and Economic Expediency, by A. H. Armstrong. A very interesting discussion followed. April 8. Attendance 131.

BRANCH MEETINGS

University of Alabama

Machine-Shop Practise, by Mr. Farabee.

Telephone Communication, by C. M. Lang. March 18.

Insurance of Electrical Instruments, by W. F. Graham. April 1. Attendance 9.

University of Arizona

Address by Professor S. M. Fegtly, Head of the Law Department. Refreshments were served. March 19. Attendance 20.

Bucknell University

A business meeting was held, at which A. L. Huffman was elected Secretary and Treasurer to fill the vacancy of F. H. Brown who recently left the University. March 26. Attendance 24.

University of California

Inspection trip through the plant of the Pacific Gas and Electric Company at Vacaville. A noonday luncheon was served by the Company, and everything combined to make the trip most enjoyable. March 15. Attendance 55.

Motion-picture reels from the University of California Extension Division. Held jointly with the A. S. M. E., the A. E. & M. E. March 19. Attendance 45.

Carnegie Institute of Technology

Railway Signalling, by Robert M. Gibson, Union Switch and Signal Company. March 5. Attendance 50.

Protection of Transmission Lines, by H. T. Langstaff, West Penn Power Company. Interesting discussion followed. April 2. Attendance 100.

Case School of Applied Science

The Future of Radio, by Harry Mount. A new R. C. A. super-heterodyne receiver was demonstrated. March 21. Attendance 33.

Catholic University of America

A moving picture was shown, entitled "Story of the Electric Meter. March 27. Attendance 31.

The Synchronous Converter, by Professor J. McKavanaugh. The lecture was illustrated and followed by a smoker. April 10. Attendance 20.

Clarkson College of Technology

Pictures of railroad electrification were shown. March 19. Attendance 15.

Clemson Agricultural College

A review of addresses presented at the Fortieth Anniversary Celebration of the Institute. April 3. Attendance 24.

University of Colorado

The Economics of Electric Railway Engineering, by Professor M. S. Coover. Roy Kuhlman gave a report on the Denver Section Meeting. February 27. Attendance 35.

Cooper Union

Industrial Motor Control, by C. F. Scott. March 14. Attendance 80.

Denver University

Modern Improvements of Electric Equipment, by F. C. Hanker, Westinghouse Electric & Manufacturing Co. The lecture was illustrated with slides. March 24. Attendance 25.

Report of Recent Developments of High-Voltage Phenomenon, by T. F. Johnson. Georgia Railway and Power Company.

Report on Method of Constructing Transmission Lines, by G. C. Shores. April 4. Attendance 17.

University of Florida

Telephone Engineering, by C. C. Voyle. March 17. Attendance 25.

Iowa State College

Telephone Repeaters, by R. I. Wilkinson. A film entitled "Romance of Rails and Power" was shown. March 5. Attendance 170.

State University of Iowa

Aerial Photography, by E. V. John.

History and Development of the Hydroelectric Plant of the State University of Iowa, by E. J. Karsten. March 10. Attend-44.

What the Professional World Expects of the Engineer, by Arthur Huntington, Iowa Railway and Light Company. March 17. Attendance 49.

Telephone Line Construction, by D. E. Marshall.

The Fynn-Weichsel Motor, by E. S. Moore.

Use of Powered Fuel in Heat Generation, by G. A. Meyers.

Substations of the Chicago, Milwaukee & St. Paul Railway, by O. H. Pullen. March 24. Attendance 40.

Electric Dredges Used by U. S. Army, by H. R. Phelps.

Distribution Systems of the Commonwealth Edison Company of Chicago, by H. W. Scott.

Adaptability of a Three-Trucked Train, by T. F. Volkmer. March 31. Attendance 49.

Transmission at 220,000 Volts, by E. F. Reihman.

Office Work of a Telephone Company, by A. M. *Wilbur*. April 7. Attendance 43.

Kansas State College

The Evolution of the Elements, by Professor J. L. Brenneman. March 19. Attendance 47.

University of Kansas

The meeting was devoted entirely to business. February 14. Attendance 48.

The Testing Laboratory of the General Electric Company, by Ross I. Parker. February 28. Attendance 51.

Lafayette College

The Applications of the Relay in Power Transmission Lines, by Mr. Green, Pennsylvania Power & Light Company. March 1. Attendance 19.

Mechanical and Hand-Operated Relays, by Professor King. The lecture was illustrated with slides. March 8. Attendance 19.
The Electron Theory and Some of Its Applications, by Professor King. March 15. Attendance 19.
The Production of Electrons by Emission and Collision, by Professor King. March 22. Attendance 19.
The Applications of Electrons in the X-Ray Tube, the Radio Tube and the Rectifier, by Professor King. March 29. Attendance 19.

Marquette University

The meeting was devoted to the inspection of the plant of the Louis-Allis Company. March 13. Attendance 46.

Lehigh University

Automatic Train Control, by Warren Bridgam, student.
Problems in Engineering of the A. T. & T. Co., by O. W. Eshbach, Bell Telephone Company of Pennsylvania. The talk was illustrated with films and slides. March 27. Attendance 57.
Railway Electrification, by Mr. Alrich of the General Electric Company. The talk was illustrated with moving pictures and slides. April 10. Attendance 77.

University of Maine

Alms and the Man, by Professor W. J. Creamer.
The Lafayette Radio Station, by George C. Barney. March 22. Attendance 13.

Engineering School of Milwaukee

Characteristics and Design of Instrument Transformers, by E. W. Foster, Packard Electric Company. The lecture was illustrated. March 19. Attendance 29.

University of Missouri

Two reels of pictures from the General Electric Company, giving views of the plants at Schenectady, Pittsfield, etc., were shown. March 24. Attendance 48.

Montana State College

A film on carborundum manufacture was shown, followed by a lecture. March 4. Attendance 64.
A film and lecture on work of the General Electric Company, by C. A. Champ. March 18. Attendance 68.
Abstracts from current periodicals were given by six students. April 1. Attendance 98.
Abstracts from current periodicals were given by the Seniors and Juniors. April 8. Attendance 88.

University of North Carolina

The Transmission System of Manhattan Island, by Professor Albrecht Naeter. April 10. Attendance 29.

University of North Dakota

Some Factors in the Making of an Engineer, by Professor D. R. Jenkins.
History of the American Institute of Electrical Engineers, by A. W. Ebenhahn, student. March 10. Attendance 12.

University of Notre Dame

Induction Generators, by Arthur Butterfield.
Electric Railways; Comparison of Over-head Wire and Third Rail Systems, by Michael Adrian. March 17. Attendance 26.
Recent Developments in Artificial Lighting, by C. J. Stahl, Westinghouse Elec. & Mfg. Co. A novel demonstration accompanied the lecture. March 31. Attendance 35.

Ohio Northern University

Mercury-Vapor Turbines, by Professor Campbell. The meeting was in the form of a smoker. March 13. Attendance 38.
The Resources of the Philippine Islands, by Mr. Sese. April 3. Attendance 20.

Oklahoma A. & M. College

Simultaneous Broadcasting, by Professor J. C. Kositzky.
An Outline of Organization of Pole-line Construction Gangs, by Roy Hayman. March 3. Attendance 14.

University of Oklahoma

Carrier-Current Telephony, by Robert Langdon, General Electric Company.
Ontario Hydroelectric Plant of Niagara Falls, by Maurice L. Prescott. March 27. Attendance 24.

University of Pittsburgh

Perpetual Motion Machines, by D. W. C. Molter.
Application of Electrical Equipment to Coal Mines, by L. Z. Ludorf. March 14. Attendance 21.
Engineering Finance, by J. S. Frances, Bell Telephone Company. The speaker explained the financial aspect of the construction and operation of two typical telephone exchanges illustrating with charts and curves. March 21. Attendance 60.
The evening was devoted to a general talk by R. V. Becket student, consisting of advice referring particularly to the course to be pursued by the engineering student after graduation. This was one of the most valuable talks given during the year. April 4. Attendance 24.

Purdue University

Opportunities in Hydraulic Development, by Professor F. W. Greve. February 27. Attendance 80.
Recent Engineering Achievements by H. W. Cope, Westinghouse Electric and Manufacturing Company.
The Problem of the Engineer of Tomorrow, by C. S. Colz of the Westinghouse Electric and Manufacturing Company. March 11. Attendance 90.
A demonstration of corona loss was given by Professor Harding, assisted by R. H. George. The speakers explained the various difficulties encountered in the operation of high-tension transmission lines. April 1. Attendance 140.

Rensselaer Polytechnic Institute

The Story of the Electric Meter was shown, produced by the Sangamo Electric Company. March 13. Attendance 76.

Rhode Island State College

This was the first meeting, called for the purpose of organizing the Branch. The following officers were elected: Chairman, Matthew Chappell; Secretary, C. Stewart North; Executive Committee, Matthew Chappell, Raymond Sutcliff, John Tower, Raymond H. Little, Professor William Anderson. March 26. Attendance 36.

Rose Polytechnic Institute

This was the first meeting of the year, at which the following officers were elected: Chairman, Paul Wilkens; Secretary, Robert A. Reddie. February 15. Attendance 25.
The meeting was devoted to a talk by Mr. Hager of the General Electric Company, who explained to the students the opportunities for technical graduates with that company. A motion picture was shown of the technical graduates at work in the various plants of the Company. March 7. Attendance 36.
The Oscillograph, by Professor Stone. This was an illustrated lecture. March 21. Attendance 18.

Rutgers College

The Steam Turbine and Its Working, by A. Rennitch.
The Cooling of Electric Machines, by W. G. Wright.
The Value of Recording Instruments in a Power Plant, by P. Lomet. March 20. Attendance 18.
Human Engineering; the Student, the Engineer, the Man, by Farley T. Osgood, Vice-President and General Manager, Public Service Electric Company. April 10. Attendance 46.

University of Southern California

The meeting was addressed by Professor Biegler, who gave a short talk on the advancement of the Electrical Engineering Department at the University of Southern California. March 5. Attendance 31.

Stanford University

Hydroelectric Development on the Pacific Coast and Opportunities for Employment Therein, by Professor Harris J. Ryan, President of the A. I. E. E. March 11. Attendance 32.

A. & M. College of Texas

The Manufacture of Insulators, by Mr. Kuehn.
Operation of the Diesel Engine, by Mr. Alds.
The Natural Sources of Power in the United States, by Mr. Palmer. March 21. Attendance 35.

University of Utah

The Industrial Relations of Large Manufacturing Concerns and Student Engineers, by Mr. Coler of the Westinghouse Electric and Manufacturing Company. January 29. Attendance 172.
The meeting was devoted strictly to business. Guy Singleton was elected Vice-Chairman to replace C. Haylor, who is leaving school. March 18. Attendance 15.
Induction Motor to Improve Power Factor, by H. Van Wyke. The Fynn-Weichsel Motor was described and explained. April 3. Attendance 18.

Virginia Military Institute

Treatment of Oil to Make Gasoline, by J. M. S. Waring. February 25. Attendance 25.
Water Power of the Colorado River, by John C. Hoyt of the U. S. Geological Survey. Slides and motion pictures were shown. Joint meeting. March 7. Attendance 500.
The Story of Water, by John C. Hoyt. Slides and motion pictures supplemented the lecture. March 8. Attendance 150.
Modern Telephone Practise, by J. C. Vandergrift, Chesapeake and Potomac Telephone Company. The lecture was illustrated. March 13. Attendance 55.
Colorado River Project, by F. Gregory.
How to Make Steam Do Double Duty, by C. M. Thomas.
England's Greatest Power Station, by J. C. Baird.
Super Synchronous Motor, by H. Adkins. March 24. Attendance 48.

State College of Washington

Advantages of Electrification of Railways, by H. F. Lickey. February 26. Attendance 48.

University of Washington

Recent Developments in Radio, by J. R. Tolmie. The speaker dealt mainly with the work done on four-element vacuum tubes. April 1. Attendance 35.

Washington University

Steam-Railroad Electrification, by A. S. Schoeman. The lecture, illustrated by lantern slides, described briefly eleven distinct electrifications of railroads. February 12. Attendance 36.
A brief demonstration of the high-frequency, high-voltage apparatus of the University was given by E. B. Williams, Instructor in Electrical Engineering at Washington University. The speaker explained how artificial lightning was produced. A film illustrating the details of the test course given to technical graduates by the General Electric Company was also shown. March 4. Attendance 33.

University of West Virginia

Transformer Maintenance, by Mr. Pitsenberger.
Telephone Transmission, by Mr. Rosier.
High-Voltage Insulation, by Mr. Naylor.
Street Railways, by Mr. Hutchinson.
Organization of Modern Electric Railways, by Mr. Callahan.
Centrifugal Oil Pumpers, by Mr. Davis.
Electric Fountain of Youth, by Mr. West.
Need for Standard Frequency, by Mr. Winter.
Resistance of Electrical Connections, by Mr. Worden.
Progress of United Railway of St. Louis, by Mr. Porter.
Frequency Problems in Japan, by Mr. Witt.
Theory of Varley Loop, by Mr. Steele. March 5. Attendance 31.
Modern Methods of Testing Alternators, by Mr. Pitsenberger.
Hydroelectric Giant, by Mr. Jones.
Power Plant of Chili Exploration Company, by Mr. Holmes.
Shaft Currents of Electrical Machines, by Mr. Chabourel.
Central Station vs. Mine Plant for Coal Mine Electric Power, by Mr. Copley.
Large Hydroelectric Units, by Mr. Roush.
Some Troubles in Electrical Equipment, by Mr. Pugh.
Electric Welding, by Mr. Reynolds.
Totalization of Power Readings, by Mr. Crush.
Power Pulsations Due to Synchronous Machines, by Mr. Henderson. March 12. Attendance 28.
Efficiency of Electric Furnaces, by Mr. Barone.
The Light of Knowledge and the Knowledge of Light, by Mr. Pitsenberger.
Carrier Currents over Telephone Lines, by Mr. Davis.
High-Voltage Circuit Breakers, by Mr. Callahan.
Central-Station Power and Electric Railways, by Mr. Winter.
Telephony on Great Western Power Company Lines, by Mr. Naylor.
Power-Station Lighting, by Mr. Worden.
Counting Traffic on Electric Railways, by Mr. Porter.
Re-babbitting Motor Bearings, by Mr. Witt. March 26. Attendance 30.

University of Wisconsin

The Fynn Weichsel Motor, by Mr. Felton, Wagner Electric Co., Milwaukee. Joint meeting with Madison Section. March 12. Attendance 35.
Business meeting. March 26. Attendance 32.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers as a cooperative bureau available only to their membership, and maintained by contributions from the societies and their individual members who are directly benefited.

MEN AVAILABLE.—Brief announcements will be published without charge and will not be repeated, except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will, it is hoped, be sufficient, not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case and with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

(For other employment announcements see page 34 of the Advertising section.)

POSITIONS OPEN

ENGINEER, college graduate, with about four years experience, preferably transmission, distribution, with some power station construction, design and operation, for position in engineering department of company managing public utilities. State education; experience and salary expected. Location, New York. R-3714.

DISTRICT SUPERINTENDENT to take charge of important district of utility which is growing rapidly. Must understand construction and maintenance of transmission, distribution and railway lines, transmission, distribution and customers substations, meters and the standard Public Utilities Commission Classification of Accounts. Location, South. R-3688.

ELECTRICAL ENGINEER, experienced in design and construction of modern transmission, distribution and railway substations, customers installations, transmission lines on towers or poles, and distribution systems. Must be capable of independent work. Previous employment in position of similar responsibility necessary. Location, Central States. R-3689.

CHIEF ELECTRICAL ENGINEER, to take complete executive charge of the electrical engineering department for a utility owning a number of high-tension central stations. Must have been employed very recently in similar capacity or have lately held responsible electrical engineering position with large manufacturer of electrical central station equipment. Salary $7500 a year, minimum. R-3525.

GRADUATE ELECTRICAL ENGINEER for editor of trade paper. Editorial experience essential, engineering and construction experience also

desirable. Application by letter giving details of experience. R-3553.

CHIEF OPERATING ENGINEER, for new works now being erected in northern New Jersey, generating own power, light and gas, initial installation 8000 kw. turbo generators with development plans up to 20,000 kw., including other equipment, to make a complete power plant for industrial purposes. Ability to direct operation, testing and maintenance essential. A combination of technical knowledge and practical experience preferred. In reply please give full details as to age, experience, education and salary desired. Location, New Jersey. R-3793.

MEN AVAILABLE

ELECTRICAL ENGINEER, with B. E. E. and M. Sc. degrees. Age 31, married. 3 years G. E. Company test and 4 years anthracite mine experience covering installation, maintenance and operation of electrical equipment generally, including power plant, substations and power lines. Can organize and handle men. Excellent references. Student Alexander Hamilton Institute, midwest preferred. B-7065.

ELECTRICAL TECHNICAL GRADUATE desires to locate with architect or contractor where he will have opportunity to learn electrical equipment arrangement, estimating, etc. No objection to starting at tracing. B-7024.

WORKS ENGINEER, MAINTENANCE ENGINEER, 15 years' experience, installation and maintenance of mechanical and electrical equipment in large industrial plants. Construction and operation of power plants. Building construction and repairs. Age 35, married. Now available. Salary $3600. B-2696.

TEACHER, 36, married, M. E. and M. E. E. Cornell, Assoc. A. I. E. E. 5 years' manufacturing and 7 years' teaching experience. Available September for associate or assistant professorship in eastern or middlewest university. B-7181.

ELECTRICAL GRADUATE, 2 years' experience on power house construction, 8 months motor and generator testing, 8 months radio telegraphy work. Desires engineering work. Age 25, Assoc. A. I. E. E. Not employed since March 27, 1924. B-7760.

ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING desires postion in educational institution. Two years now as commercial engineer for a modern central station. Eight years' teaching experience. Four years of practical experience in electrical work. Age 39, married, American of English descent. Qualified to teach technical theory and practise and commercial engineering. B-198.

ELECTRICAL ENGINEER, technical graduage, wishes to connect with a live engineering organization. Twelve years wide experience in electrical design, office and field, of power stations, substations, industrial buildings, with large engineering company. Have had responsible charge in field of appraisal of electrical properties. Associate A. I. E. E., N. E. L. A. Holds state license. B-5393.

YOUNG MAN at present employed as construction foreman and engineer with a concern doing electrical and mechanical contracting, desires to make a connection with an engineering firm as engineer. Experience and technical education along lines of electrical and mechanical nature including industrial plant layout. B-7789.

ELECTRICAL ENGINEER, B. S. and E. E. degrees, twelve years' experience on electric railways, location Chicago. Salary $4000, available on one month's notice. B-7799.

PROFESSOR OR ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING, graduate electrical engineer with broad commercial and teaching experience, specializing in electrical machinery, electric railways, and power transmission. East, Middlewest or West. Minimum salary $3500. B-2868.

GRADUATE ELECTRICAL ENGINEER experienced in design, construction and operation of power and industrial plants. High and low tension transmission, reports, appraisals, tests, inspection, etc. B-7816.

ELECTRICAL ENGINEERING GRADUATE, age 28. Two years U. S. Army, four years telephone transmission and equipment maintenance work. Would like to become connected with some small growing manufacturing concern of radio or electrical equipment. B-7739.

ENGINEER, 39, married, family. Experienced experimental laboratory and electrical research, textile, industrial plant chief and maintenance and betterment. Location, New England. B-6874.

GRADUATE HIGH STANDING UNIVERSITY, B. S. (E. E.) '22 graduate students course one largest manufacturing companies of America, six months office sales central station. equipment, enrolled modern salesmanship course. Desires position sales field of engineering. Location preferred, West or Middlewest but not essential. Now employed. B-7810.

ASSISTANT TO OPERATING ENGINEER, college graduate E. E. 26 years old, married. Desires position in above or similar capacity. Experience includes four and one half years telephone research and design, four years central station, substation, transmission line and distribution, engineering and design for public utility and industrial plant. Location, immaterial. B-7809.

ELECTRICAL ENGINEER. Member, A. I. E. E. License engineer, N. Y. State, have 25 years in office, shop, power stations, and high tension lines, design, construction and operation. Last 7 years engineer for large industrial, three plants-electric furnaces 25,000 kv-a. Previous with hydroelectric stations positions up to 6 years as superintendent 80,000 h. p. rotary stations 45,000 kv-a. Will accept agency for equipment in Western N. Y. B-6891.

DEVELOPMENT ENGINEER, technical graduate, Mem. A. I. E. E. Thirteen years investigation, design and manufacture, six years installation, five years sales. Experienced in telegraph, telephone, radio and sound ranging apparatus and construction, submarine cable testing and laying, cable machinery, submarine boats, automobiles and trucks. Age 47, married, excellent health. B 5948.

GRADUATE ELECTRICAL ENGINEER, 1920, married, age 27. Two years general distribution and power line work, also five months test work on small motors and one years experience as sales engineer. Also four years experience as a commercial photographer. Desires position where ability, hard work and attention to details combined with a varied business experience will lead to rapid advancement in engineering and executive position. Location, eastern Pennsylvania preferred. Salary $200 a month. Available July 1st. B-7827.

ELECTRICAL ENGINEER, age 45, married, with 15 years experience in research and development work of electrical apparatus. Thoroughly grounded in physics. Familiar with high frequency electricity, spectroscopy and high-vacuum work. Specialized in development and design of laboratory equipment. Knowledge of foreign languages. Available about May first. B-7829.

LAWYER AND TECHNICAL EXPERT, patent office and court practise, certified by the U. S. Civil Service Commission as Technical Patent Expert, Expert Patent Investigator, Specification Writer and Prosecutor. Engineering experience covering research, development, testing, installation, operation and maintenance. Mem. A. I. E. E., A. A. A. S., and Soc. Am. Military Engineers. Desires connection with patent law, engineering, manufacturing or other industrial concern. Location preferably New York. B-7252.

MECHANICAL AND ELECTRICAL ENGINEER, age 33, successful as plant engineer and superintendent with large manufacturing concern using process steam, high pressure boilers, turbine plant, considerable machinery, locomotives and rolling stock, wishes to locate in East. References from past employers. Available on short notice. B-6852.

GRADUATE ELECTRICAL ENGINEER, desires position with company where demonstrated ability, work and persistence will insure rapid advancement. 1¾ years design and research in engineering department of a large corporation. Half a year electrical repair work. Speaks one foreign language fluently, good working knowledge of three others. Member A. I. E. E. B-7830.

ELECTRICAL ENGINEER, university graduate. Fifteen years experience in design and construction of power plants and substations for light, power and traction, in calculating costs, making estimates and reports and taking care of commercial and accounting ends, executive ability. Knows several languages. At present in charge of office force designing steam plants and substations, desires position as designing or commercial engineer or chief draftsman. B-7841.

PROFESSOR OF ELECTRICAL ENGINEERING, B. S. in E. E. June 1916. Two years in engineering department of concern manufacturing electrical equipment. Five years' teaching experience. At present doing graduate work in electrical engineering. Desires teaching position in the electrical engineering department of a college or university. B-7840.

MECHANICAL AND ELECTRICAL ENGINEER. B. S. in E. E. 1915. Age 32, married. G. E. Test. Now assistant to leading mechanical engineer, researches, testing, conducting investigations and writing reports. Experienced in operation all power apparatus. Special studies all kinds internal combustion engines, including Diesel, and of motor-driven domestic appliances, including refrigerators. Desires greater opportunity. Available about August 1st, salary around $5000. B-7818.

RECENT GRADUATE, B. S. in E. E. Has no electrical experience, desires position with opportunity to advance in the profession. Available in one week. B-7270.

MECHANICAL AND ELECTRICAL ENGINEER, age 42, college graduate. Nineteen years' practical experience. Five years teaching in leading university, six years electrical engineer with leading manufacturing company, two years electrical engineer Public Service Commission work, seven years mechanical and electrical engineer large public utility, in charge of rates, power plant construction and operation, distribution and substation construction and operation. B-7848.

MECHANICAL-ELECTRICAL ENGINEER age 31, 10 years experience design, drafting, shop and patent routine, automotive machinery, tools, industrial and power plants, layouts. Knowledge of German, Bohemian, some French. Available May 15th. B-7478.

INSTRUCTOR of laboratory and applied electricity. Age 28 years, with over eight years of electrical experience and three years of teaching experience, desires position as electrical instructor in a junior high school, or laboratory instructor in a senior high school, or vocational school. Hold a Pennsylvania State Standard Certificate. B-7723.

GRADUATE ELECTRICAL ENGINEER, at present employed as assistant electrical superintendent in large industrial plant. Would like position as electrical superintendent in large industrial plant. Location immaterial. Foreign service agreeable. Further particulars upon request. B-7862.

REGISTERED ENGINEER, electrical experienced in design, construction and maintenance of power plants, substations, etc., desires position with consulting and contracting engineers. Pennsylvania license. B-7859.

MARINE ENGINEER with unlimited chief engineers marine license and a university degree in electrical engineering, desires position where he can use both steam experience and electrical education. B-7860.

ELECTRICAL ENGINEER, age 28. Desires connection with public utility or contracting company as construction, operating or maintenance engineer. Testing and construction experience with General Electric Company. At present employed as field superintendent for combustion control engineers. Available in six weeks. Present salary $3000. B-7861.

GRADUATE IN ELECTRICAL engineering with wide experience in both electrical and mechanical trades, including power plant. Wishes to leave the mines. Married, age 36. B-7866.

EXECUTIVE ENGINEER, twelve years responsible charge of engineering and executive work with prominent public utilities consulting engineers, and five years with large electrical manufacturer. Experience covers engineering and design, supervision of construction and operation, rate, future development and financial questions. Can take responsible charge of broad administrative and engineering work. B-7867.

ELECTRICAL ENGINEER with twenty years' experience in large central stations. Desires position in vicinity of New York, or eastern states. Age 45, married. B-7874.

ELECTRICAL ENGINEER, university graduate. Westinghouse students training course. Five years power plant experience with public utility. Experience includes test and efficiency work and operation, three years as assistant superintendent in charge of operation. Position of executive nature with opportunity for advancement desired. Available one months notice. B-7856.

ELECTRICAL ENGINEER, technical graduate E. E. Mem. A. I. E. E., N. E. L. A., A. A. E. R. A. Age 44, married. Twenty years electrical lighting and railways of same management of properties and in home office. Design and operation of transmission and distribution, municipal lighting, meter and regulator practise, power factor connection, power contracts, railway distribution, automatic signals, electrolysis and welding, track bonding. Available two weeks notice or less. B-7220.

ELECTRICAL ENGINEER, technical graduate. Seventeen years experience in electrical control manufacture and sales, industrial operation, engineering and research. Desires to locate with an electrical manufacturer, either in production or sales engineering, or with a consulting engineer or firm of established reputation. Only a permanent proposition considered. Location preferred, Philadelphia or New England. B-6694.

PUBLIC UTILITY MANAGER, position wanted as manager of electric light property in town of 2500 to 5000, or as manager of electric light and water departments. Experienced in engineering and operation departments of large electric companies, with construction company on electric transmission lines and waterworks, one year owner and manager of small electric plant, University training, not a graduate. Age 26 married. Middlewest preferred. B-7876.

PROFESSOR OF ELECTRICAL ENGINEERING in a strong state university, desires a change only to secure executive responsibility and, increased income. Age 39, health excellent married. Member of honorary societies. The best of collegiate and technical training, valuable construction and consulting experience as well as several years in present position. B-7925.

ENGINEER-STATISTICIAN, B. S. in E. E., three year accounting course. Three years statistical work on large underground distribution system for perpetual inventory and tax report. Also municipal and field experience on O. H. systems, street lighting, etc. Some purchasing. Salary desires, over $40.00. 35 years old, married. B-197.

METER ENGINEER, graduate electrical engineer, six years' experience with electrical utilities, mostly with meter work, have broad theoretical and practical knowledge of testing, metering, installation, records, calibration and repair of all types of watthour reactive and kilovolt-ampere meters, switchboard and portable instruments and relays. Special knowledge of the latest installation methods. Available for responsible position wtih progressive utility company. Minimum salary to start $200. B-7910.

RECENT GRADUATE B. S. in Electrical Engineering with some experience in steam electric power plant testing, a. c. motor testing and production. Desires a permanent position with some central station, or manufacturing concern where a hard worker is appreciated. Age 26, single. Residence, Ohio. Location immaterial. Available at once. B-7908.

ENGINEER AND UTILITY MANAGER available for position with electric public service company or engineering firm. Have been manager of a large property for a number of years. Thoroughly experienced engineering, construction and operation, including power plants, transmission and distribution systems, substations, commercial work, valuations, rates. Graduate electrical engineer, seventeen years experience, age 39. Record absolutely clean, highest references. B-7906.

ELECTRICAL ENGINEER, age 23, graduate of a recognized technical school, desires position in some college. Have had several years practical experience in telephone and radio work and several years teaching experience. Would consider a position with small remuneration if an opportunity would be given for further pursuing studies leading to a degree. B-3781.

ELECTRICAL MANUFACTURER. I am looking for a position of responsibility with small electrical manufacturer. Initial salary not important. Graduate electrical engineer, 31 years old, nine years' experience. At present, and for last three years, with small manufacturer of electrical equipment as manager, with supervision of entire business, including sales. B-7798.

RADIO ENGINEER, experienced, desires position with a university teaching radio engineering and conducting research. Finest references available. B-7886.

ASSOCIATE PROFESSOR OF ELECTRICAL ENGINEERING seeks good opportunity in teaching or industry. Masters degree from Cornell, five years of broad experience in teaching, Westinghouse test and design engineering department experience, New York Edison test. Excellent recommendations. Available in July. B-7892.

SALES ENGINEER, 26, single, M. I. T. 1918, electrical engineering. Sales experience three years along electrical lines, with prior engineering experience in steam power plants (marine). Last year and a half sales engineer and supervisor. Available on one weeks' notice. B-2225.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED APRIL 11, 1924

ALBERTS, ERNEST G., Electrical Service Inspector, Bureau of Power & Light, 120 E. 4th St., Los Angeles, Calif.

ALFORD, EUGENE CLAIR, Jr., Office of Supt. of Construction, Portland Railway, Light & Power Co., Hawthorne Bldg., Portland, Ore.

ALLEN, MATHEWES C., General Electric Superintendent, Long Bell Lumber Co. & Longview Public Service Co., Longview, Wash.

*ALRICH, JOHN D., Engineer, Railway Locomotive Engg. Dept., General Electric Co., Schenectady, N. Y.

AMES, WILLIAM EDLEY, Asst. Electrical Engineer, Dept. of Street Railways, St. Jean & Shoemaker Sts., Detroit, Mich.

ARGABRITE, CLARENCE C., Chief Electrical Engineer, Interstate Public Service Co., 1100 Wild Bldg., Indianapolis, Ind.

*ASHTON, LASTON ERIC, Lamp Inspector, Hydro-Electric Power Commission, 330 2nd Ave., Verdun, Montreal, P. Q., Can.

AXON, ALBERT EDWIN, College Apprentice, Metropolitan Vickers Co., Ltd., Trafford Park, Manchester, Eng.

BADGER, HERBERT LEON, General Plant Manager, The Bell Telephone Co. of Penna., 261 N. Broad St., Philadelphia, Pa.

BAKER, RAYMOND DANVERS, Asst. to Engineer in Charge of Distribution, Wellington City Corp., Wellington; res., Lower Hutt, New Zealand.

BAUMER, HARRY W., Technical Examiner of Efficiency, City of Chicago, City Hall, Chicago, Ill.

BELLOWS, REYNOLDS, Sales Engineer, Paulsen Spence Co., 25 Church St., New York, N. Y.

BERGENSTRAHLE, KARL IVAR LUDVIG, Designer, General Electric Co., Schenectady, N. Y.

BERNHARD, FREDERICK S., Radio Engineer, Western Electric Co., Inc., 463 West St., New York; res., Brooklyn, N. Y.

BLAIN, RAY, Telephone Plant Engineer, 7th Corps Area, Signal Corps, U. S. Army, 22nd & Hickory Sts., Omaha, Nebr.

BLEE, PAUL JOSEPH, Electrical Draftsman, Transformer Dept., General Electric Co., Ft. Wayne, Ind.

*BOASEN, FREDERICK DITTUS, Meter Tester. Public Service Co. of Oklahoma, Guthrie, Okla.

BORGMANN, CARL, Manual Equipment Development Engineer, Western Electric Co., Inc., 463 West St., New York, N. Y.

BOWMAN, CLAIR FERGUSON, Assistant, Elec. Engg. Dept., Purdue University, West Lafayette, Ind.

BRECKENRIDGE, WILBUR T., Engineer, American Tel. & Tel. Co., 195 Broadway, New York, N. Y.; res., East Orange, N. J.

BROOKS, JOHN WENDELL, Secretary, Treasurer & General Manager, Pass & Seymour, Inc., Cor. Boyd & Milton Aves., Solvay, N. Y.

BROWN, BENJAMIN, Student, Bliss Electrical School, Takoma Park, Washington, D. C.

BROWN, CHARLES WILLIAM, Short Hills, N. J.

BROWN, JOSEPH M., General Foreman, Elec. Dept., Lehigh Valley Railroad, Sayre, Pa.; for mail, Waverly, N. Y.

*BROWN, PAUL LAWRENCE, Radio Engineer, Main Street, Riverhead, N. Y.

BROWN, ROBERT CALVERT, Supt. of Substations, Dept. of Street Railways, Detroit, Mich.

BROWNE, WALTER A., Electrician in Charge, Government Printing Office, Washington, D. C.

BURKE, AFTON C., Salesman, Victor X-Ray Corp., 2503 Commerce St., Dallas, Texas.

BURNS, GEORGE J., Asst. Master Mechanic, Diamond Branch, Rome Wire Co., 56 Clyde Ave., Buffalo, N. Y.

BYRD, WENDELL MASON, Foreman, Phoenix Utility Co., Memphis, Tenn.

CALDWELL, ATHOL C. A., Asst. Electrical Engineer, Hydro-Electric Branch, Public Works Department, Wellington, New Zealand.

*CALDWELL, DUNCAN KEITH, Junior Electrical Engineer, Bureau of Power & Light, 120 E. 4th St., Los Angeles, Calif.

CALLAHAN, EDWARD S., Chief Engineer, Consolidated Telegraph & Electrical Subway Co., 54 Lafayette St., New York, N. Y.

CARLSON, J. W., Planning Engineer, Western Electric Co., Inc., 268 W. 36th St., New York, N. Y.; res., Arlington, N. J.

CARRITT, JOHN GEORGE, Plant Engineer, Rochester Telephone Corp., 95 N. Fitzhugh St., Rochester, N. Y.

*CHANDLER, LAWRENCE FRANCIS, Teacher, Industrial Science Dept., High School, Blythe, Calif.

CHANG, POW DONG, Switchboard Engg. Dept., General Electric Co., 19 N. Ferry St., Schenectady, N. Y.

CHARLESWOOD, SHERIDAN G., Chief Electrician, Power Station, Indiana Service Co., Ft. Wayne, Ind.

*CHEN, YUHAN, Special Student, Ford Motor Co., Highland Park, Mich.; for mail, Anting, Kiangsu, China.

*CHILBERG, ERNEST E., Testing Electrical Apparatus, General Electric Co., Schenectady, N. Y.

CHILD, RICHARDS L., 640 Eastern Parkway, Brooklyn, N. Y.

CLYMER, CHARLES CLARENCE, Engineer, Industrial Engg. Dept., General Electric Co., Schenectady, N. Y.

COAN, JOHN, Chief Electrician, Rocky Mountain Fuel Co., Lafayette, Boulder Co., Colo.

COLE, EDWARD ROBERT, Supt. of Plants, No. 1 & No. 2, Acheson Graphite Co., Niagara Falls, N. Y.

COLEBROOK, HECTOR FRANK, Asst. Electrical Engineer, City of Winnipeg Hydro-Electric System, 55 Princess St., Winnipeg, Man., Can.

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*CONN, JULIUS SAMUEL, Designing Engineer, General Electric Co., Pittsfield, Mass.

*CONNOLLY, WALTER JAMES, Electrical Designing Engineer, Stone & Webster, Inc., 147 Milk St., Boston, Mass.

CORSON, ALMON JUSTUS, Electrical Tester, Standardizing Laboratory, General Electric Co., West Lynn; res., Lynn, Mass.

CRAIG, ARTHUR CONERY, Engineering Assistant, Bell Telephone Co. of Penna., 261 N. Broad St., Philadelphia, Pa.; res., Merchantville, N. J.

CRAMER, ORIS H., Switchboard Engineer, Westinghouse Elec. & Mfg. Co., 2211 Pershing Road, Chicago, Ill.

CREASER, ISAIAH, Chief Electrician, Rolls-Royce of America, Inc., Page Blvd., East Springfield; res., Springfield, Mass.

DALTON, WILLIAM JOSEPH, Inspector, Brooklyn Edison Co., 360 Pearl St., Brooklyn; res., New York, N. Y.

DAMRAU, EDWARD AVERILL, Dist. Manager, The Okonite Co., 1111 First National Bank Bldg., Pittsburgh, Pa.

*DAVIDSON, ANTHONY, Teacher, Dept. of Mathematics, Kittrell College, Kittrell, N. C.; for mail, New York, N. Y.

DAWSON, GEORGE LOUIS, Senior Aide, Elec. Engg., National Advisory Commission for Aeronautics, Langley Field, Va.

De CAMP, HARRY H., Tester, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

DEEDS, ED FAYETTE MANNSTEDT, Salesman, Victor X-Ray Corp., 208 Gloyd Bldg., Kansas City, Mo.

DIENER, EUGENE E., Chief Meter Repair Man, The Philadelphia Electric Co., 23rd & Market Sts., Philadelphia; res., Sharon Hill, Pa.

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*DUDLEY, HOMER WALTER, Telephone Transmission Research, Western Electric Co., Inc., 463 West St., New York, N. Y.

EBERLE, WILLIAM R., Asst. to Asst. Treasurer, Radio Corp. of America, 64 Broad St., New York, N. Y.

EDWARDS, LYLE LEO, Asst. Engineer, Halcomb Steel Co., Syracuse, N. Y.

ELLIOTT, W. N., Sales Manager & Secretary, N. Slater Co., Ltd., Hamilton, Ont., Can.

ELLIS, DELBERT, Control Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

*FARIS, ARTHUR WILLIS, Senior, Elec. Engg., Purdue University, 115 Lutz Ave., West Lafayette, Ind.

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FRASER, HENRY ERIC, Electrical Laboratory, 13 Mile Road, Royal Oak, Mich.

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*FRIEDRICH, E. J., Electric Metering, Columbus Railway, Power & Light Co., Columbus, Ohio.

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*GAMBLE, GEORGE PETERKIN, Electrician, Construction Work, General Electric Co., Boston, Mass.

GANO, HARLAN S., Electrical Engineer, Elec. Heating Engg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

*GARMAN, JOHN CLIFTON, Instructor in Physics, Oregon State College, Corvallis, Ore.

*GARTLAND, HUGH FRANCIS, Production Manager, Ace Motor Corp., 2201 E. Erie Ave., Philadelphia, Pa.

*GARTNER, CHARLES ECKERT, Jr., Electrical Tester, Philadelphia Electric Co., 23rd & Market Sts., Philadelphia, Pa.

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*GLICKMAN, HARRY, Inspector, Toronto Hydro-Electric System, Duncan & Nelson Sts., Toronto, Ont., Can.

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GOSNELL, HARPUR ALLEN, Instructor, Dept. of Engineering, Princeton University, Princeton, N. J.

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GRAVES, WALTON PEYTON, Electrical Draftsman, Alabama Power Co., Brown Marx Bldg., Birmingham, Ala.

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GREB-LASKY, FRANK J., Foreman, Electric Construction, Public Service Production Co., 86 Park Pl., Newark; res., Paterson, N. J.

GREENMAN, J. IRVING, Section Head, General Electric Co., East Lake Road, Erie, Pa.

GRISWOLD, ERNEST CARL, Electrical Engineer, Induction Motor Engg. Dept., General Electric Co., Schenectady, N. Y.

GROSS, HOWARD WILLIAM, Principal, Spring Garden Institute, Broad & Spring Garden Sts., Philadelphia, Pa.

HAGA, JENS, Engineering Dept., New York Edison Co., 44 E. 23rd St., New York.; res., Brooklyn, N. Y.

HALASEY, FRANCIS RICHARD, Junior Engineer, Aluminum Ore Co., 330 Missouri Ave., East St. Louis, Ill.

HALSTEAD, JASPER MORTIMER, Engg. Dept., Kansas City Power & Light Co., 1330 Grand Ave., Kansas City, Mo.

HAMER, WILLIAM DAVID, Manager, W. D. Hamer Co., 518 Traction Terminal Bldg., Indianapolis, Ind.

HANDY, LEE, Asst. Engineer, United Electric Light & Power Co., Fisher Bldg., New York; res., Brooklyn, N. Y.

*HANKS, ALFRED JOSEPH, Engineer, Research Dept., Western Union Telegraph Co., 195 Broadway, New York, N. Y.; res., Jersey City, N. J.

HANSEN, CHRISTIAN, Jr., Asst. Auditor, Accounts Receivable, The Minneapolis General Electric Co., 15 S. 5th St., Minneapolis, Minn.

HARDIE, EDWIN R., Supervisor of Operation Test Methods, Western Electric Co., Inc., 268 W. 36th St., New York, N. Y.

HARRINGTON, FREDERICK O., Engineer, New England Tel. & Tel. Co., 50 Oliver St., Boston, Mass.

HARRIS, B. A., Sales Representative, Westinghouse Elec. & Mfg. Co., 1137 Ohio Bldg., Toledo, Ohio.

HEBERT, JOSEPH ALEXANDRE, Division Plant Engineer, Southern Bell Tel. & Tel. Co., Charlotte, N. C.

HEIM, E. F., Engineering Assistant, Pennsylvania Water & Power Co., 1611 Lexington Bldg., Baltimore, Md.

*HERR, CLARENCE K., Electrical Engineer, General Electric Co., Schenectady, N. Y.

*HERRICK, GEORGE GRANT, Electrical Engineer, Stackpole Carbon Co., St. Marys, Pa.

HIGH, HOWARD WILLIAM, Supt. of Underground Construction, Union Gas & Electric Co., 4th & Plum Sts., Cincinnati, Ohio.

*HIGH, SELDON FRANK, Manager, G. W. Sullivan Electric Co., 118 Opera Pl., Cincinnati, Ohio.

HILLS, FREDERICK GEORGE WILLIS, Toronto Hydro Electric System, Toronto, Ont., Can.

HIRLEMAN, GLENN WENTZEL, Salesman, General Electric Co., Red Rock Bldg., Atlanta, Ga.

HITZEROTH, LORENZ CHARLES, Engineering Assistant, Public Service Production Co., 80 Park Pl., Newark, N. J.

HLAVAC, JAROSLAV G., Electrical Draftsman, Elec. Engg. Dept., Adirondack Power & Light Co., Schenectady, N. Y.

*HOLTE, HAROLD OLIVER, Research Physicist, Union Switch & Signal Co., Swissvale; res., Wilkinsburg, Pa.

HOWE, MILLARD CLIFFORD, Engineer, Southeastern Underwriters Association, Atlanta, Ga.

*HOWE, WILFRED H., Student, Harvard Graduate School of Business Administration, Cambridge; for mail, Worcester, Mass.

HOY, JOHN MITCHELL, A. C. Switchboard Operator, West Penn Power Co., Springdale, Pa.

HOYT, MYRON ARDEN, Draftsman, Gibbs & Hill, Pennsylvania Sta., New York; res., Mt. Vernon, N. Y.

*HUGHES, HARRY EDWARD, Electrical Contractor & Radio Dealer, Miami & Rugby Aves., Terrace Park, Ohio.

JAPP, ALBERT L., Draftsman, Interborough Rapid Transit Co., 98th St. & 3rd Ave., New York, N. Y.; res., Morsemere, N. J.

JARDEN, GEORGE HUHN, Transmission & Distribution Design Dept., Philadelphia Electric Co., 23rd & Market Sts., Philadelphia, Pa.

*JEFFERS, LYLE M., Switchboard Operator, Utah Power & Light Co., Wheelon, Utah.

JONES, HARRY MAXWELL, Distribution Engineer, Engg. Dept., Idaho Power Co., Boise, Idaho.

KEITH, JOHN MOSES, Plant Dept., American Tel. & Tel. Co., 1411 Hurt Bldg., Atlanta, Ga.

KELLY, ORION E., Chief Electrician, Tennessee Eastman Corp., Kingsport, Tenn.

KIELEY, MAURICE E., President & General Manager, The Kieley Electric Co., 127 E. Pearl St., Cincinnati, Ohio.

KILGOUR, DAVID GRANT, Cable Splicers Helper, Pacific Gas & Electric Co., 17th & Clay Sts., Oakland, Calif.

KIMBALL, GEORGE EDWARD, Electrical Engineer & Contractor, 5 Spring St., Nashua, N. H.

KOBER, PAUL ALEXANDER, Engineer, Engg. Dept., General Electric Co., Harrison; res., East Orange, N. J.

KOSTKOS, HENRY JOHN, Telephone Engineer, Western Electric Co., Inc., 268 W. 36th St., New York; res., City Island, N. Y.

*KRAEMER, CHARLES MARTIN, Substation Operator, Commonwealth Edison Co., 521 Plymouth Court, Chicago, Ill.

KRAMER, MAX GEORGE, Instructor, Elec. Dept., Spring Garden Institute, Broad & Spring Garden Sts., Philadelphia, Pa.

KRIEGL, OTTO, Thomas Meter Dept., Cutler-Hammer Mfg. Co., Milwaukee, Wis.

KUSHNER, NICHOLAS CHARLES, Engineering Dept., New York Edison Co., 44 E. 23rd St., New York; res., Brooklyn, N. Y.

*LEARY, JOHN J., Sales Engineer, General Electric Co., Schenectady, N. Y.; res., Naugatuck, Conn.

LEIGHTON, HAROLD D., Electrician, Minnesota Electric Light & Power Co., Cushing, Okla.

*LENMARK, OAL JOHN, Negative Distribution Engineer, Twin City Rapid Transit Co., 1 So. 11th St., Minneapolis, Minn.

LLORENS, FELIX LUCIANO, Electrical Engineer, The Manati Sugar Co., Manati, Oriente, Cuba.

LOZIER, JAMES D., Stores Manager, Western Electric Co., Inc., 1100 York St.,Philadelphia, Pa.

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MATHIAS, BENJAMIN, Inspector of Light & Power, City of New York, 50 Court St., Brooklyn, N. Y.

MAXWELL, ALEXANDER CARSON, Maintainance Engineer, Distribution Dept., Dallas Power & Light Co., Dallas, Texas.

McCARTHY, CHARLES PATRICK, Testing Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

McCLELLAN, EARL ALLEN, Technical Investigator, Western Electric Co., Inc., Hawthorne Works, Chicago, Ill.

McCRAY, HARRISON ROWLAND, Representative, American Electric Motors Inc., 57 Erie St., Milwaukee, Wis.

*McFARLAN, JAMES POWELL, Test Engineer, Union Gas & Electric Co., Cincinnati, Ohio.

McGANN, JAMES L., Electrician, Utah Copper Co., Magna; for mail, Salt Lake City, Utah.

*McLELLAN, JOHN DOUGLAS, Shop Manager, Canadian National Telegraphs, 99 King St., W., Toronto, Ont., Can.

McRAE, MURDOCK ARTHUR, Armature Winder, J. D. Wallace & Co., 1491 W. Jackson Blvd., Chicago, Ill.

McREYNOLDS, LOUIS RAYMOND, Estimator, Brooklyn Edison Co., 561 Grand Ave., Brooklyn; res., East Elmhurst, N. Y.

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*MOOREHOUSE, JOHN WALTER, Jr., Electrical Supervisor, M. P. & R. E. Dept., Reading Co., Reading, Pa.

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MUNCH, WILLIAM, Asst. Instructor, Elec. Dept., Spring Garden Institute, Broad & Spring Garden Sts., Philadelphia, Pa.

MUNN, WILLIAM HENRY, Railway Sales Engineer, Australian Westinghouse Co., Cathcart House, 11 Castlereagh St., Sydney, Australia.

NILSSON, NILS JOHAN EINAR, Designer, Switchboard Dept., General Electric Co., Schenectady, N. Y.

OHTSUKI, TAKASHI, Professor, Kumamoto Technical College, Japan; for mail, Stanford University, Calif.

*O'KEEFE, JAMES J., Student's Test Course, General Electric Co., Bloomfield, N. J.; for mail, Waterbury, Conn.

ORINSKY, EMILE, Leather Goods Maker, Peerless Leather Goods Co., 19 High St., Boston, Mass.

ORTENBLAD, RODOLPHO, Post Graduate Student, Middle Section, North College, Union College, Schenectady, N. Y.

OTTO, GEORGE, Draftsman, Western Electric Co., Inc., 463 West St., New York, N. Y.; res., Weehawken, N. J.

OXEHUFWUD, ANDERS GUSTAF FREDRIK, Designer, Switchboard Dept., General Electric Co., Schenectady, N. Y.

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POIRER, LEO J., Electrician, 38 Linden Ave., Somerville, Mass.

PORT, FRANK H., Chief Engineer, Grand Rapids Show Case Co., 6th & Hoyt Sts., Portland, Ore.

PRINGLE, ARTHUR E., Vice-President & General Manager, Pringle Electric Mfg. Co., 1910 N. 6th St., Philadelphia, Pa.

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*RUESE, WILBUR HERMAN, Dist. Meter Superintendent, Kansas Electric Power Co., Emporia, Kans.

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SEALEY, GARRETT LINDERMAN, Asst. Electrical Engineer, Philadelphia & Reading Railway Co., Reading, Pa.

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SHAFF, JOY EARL, Chief Electrician, Front St. Plant, Erie Lighting Co., Erie, Pa.

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*SHANER, BERNARD K., Asst. Electrical Engineer, Madeira Hill & Co., Frackville, Pa.

*SHELTON, PAUL, Meter Tester, City of Stillwater, Stillwater, Okla.

SHUPE, H. P., Electrician Construction, Metropolitan Power Co., Middletown, Pa.

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SNOW, VINCENT ALBERT, Electrical Contracting, 4721 Delmar St., St. Louis, Mo.

SOMERS, JOHN CAMERON, Schedule Engineer, Planning Div., Duquesne Light Co., 501 Chamber of Commerce Bldg., Pittsburgh, Pa.

SOMMER, PAUL H., Superintendent of Distribution, West Virginia Utilities Co., Morgantown, W. Va.

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*STAFFORD, JOHN KENDRICK, Instructor, Dept. of Mathematics, Rensselaer Polytechnic Institute, Troy, N. Y.

STAHLEY, ERNEST P., Student, Engineering School, Drexel Institute, 5557 Osage Ave., Philadelphia, Pa.

STAUFFER, J. H., Estimator & Engineer, Craig Electric Co., 418-6th Ave., Pittsburgh, Pa.

STEARNS, HOWARD REYNOLDS, Electrical Engineer, Dept. of Street Railways, Shoemaker & St. Jean Aves., Detroit, Mich.

STECKER, GEORGE F., Asst. Manager, Construction Dept., Consumers Power Co., Jackson, Mich.

*STEIN, WALTER CHARLES, Partner, Cliffside Park Press, Inc., 704 Anderson Ave., Grantwood, N. J.

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TANBERG, RAGNAR, Engineering Dept., Adirondack Power & Light Corp., Schenectady, N. Y.

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*TARPLEY, HAROLD IRWIN, Instructor, Dept. of Electrical Engineering, Pennsylvania State College, State College, Pa.

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USSELMAN, GEORGE LINDLEY, Asst. Engineer, Radio Corp. of America, Marion, Mass.

VACHA, FRED, Constructor, 540 W. 122nd St., New York, N. Y.

VALLEN, EARL J., Manager, E. J. Vallen Electrical Co., 13 S. Canal St., Arkon, Ohio.

VAN INWEGEN, LYMAN C., Chief Engineer, Public Service Electric Co. of New Jersey, Red Bank, N. J.

VAN PELT, ARTHUR A., Chief Engineer, B. A. Wesche Electric Co., 1622-28 Vine St., Cincinnati, Ohio.

*VERDIN, FLORENT EUGENE, Syracuse Manager, Schiefer Electric Co., 615 City Bank Bldg., Syracuse, N. Y.

VICARY, LOUIS CLAUDE, Resident Electrical Engineer, Springs-Ellesmere Power Board, Leeston, Canterbury, New Zealand

WAINMAN, FRANK H., General Tester, New York Edison Co., 92 Vandam St., New York; res., Brooklyn, N. Y.

*WATERS, FRANK NORTHUP, Manager, City Ice Works, 1437 Center St., Salem, Ore.

WATERS, JOHN IRVING, Superintendent, American Electrical Works, Phillipsdale; res., Rumford, R. I.

WELSH, M. G., General Manager, Citizens Gas Co., Stroudsburg, Pa.

WEST, HOMER BERNARD, Transformer Design Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.

WETHERBEE, C. PREBLE, Asst. Engineer, Bell Telephone Co. of Penna., 261 N. Broad St., Philadelphia; res., Narberth, Pa.

WHITTON, LOYAL W., Engineer, Otis Elevator Co., 2300 Stockton St., San Francisco, Calif.

WICKSTRAND, ARTHUR WILLIAM, Electrical Design, Public Service Production Co., 730 Public Service Terminal Bldg., Newark, N. J.

WIKLE, HAROLD WILSON, Salesman, General Electric Co., 123 Spring St., Atlanta, Ga.

WRIGHT, GEORGE THOMAS, Asst. Electrical Engineer, High Commissioner of India, London, Eng.

YOUNG, FREDERIC C., Asst. Engineer, Electrical Lab., Stromberg-Carlson Telephone Mfg. Co., 1050 University Ave., Rochester, N. Y.

Total 242

*Formerly Enrolled Students.

ASSOCIATES REELECTED APRIL 11, 1924

ELFTMAN, JOHN D., Supt. of Production, Public Service Co. of Colorado. First National Bank Bldg., Boulder, Colo.

SMITS, THEODORE ALBERTUS, Physics Dept., City College of New York, 139th St. & Convent Ave., New York, N. Y.

YOUNG, STUART S., Superintendent & Owner, Star Electric Co., 9 E. 9th St., Coffeyville, Kans.

MEMBERS REELECTED APRIL 11, 1924

CONNELL, HARRY WESTCOTT, Consulting Engineer, 4 Mildred Ave., Baldwinsville, N. Y.

CRANSTON, HARRY DOW, President, Cranston Engineering Co., Kneedler Bldg., Manila, P. I.

FELLOW REELECTED APRIL 11, 1924

CHACE, WILLIAM GREGORY, Partner, Sullivan, Kipp & Chace, Ltd., 302 Nanton Bldg., Winnipeg, Man., Can.

ASSOCIATE REINSTATED APRIL 11, 1924

HAYNES, HAROLD APPO, Instructor, Washington High Schools, 1523 M. St., N. W., Washington, D. C.

MEMBER REINSTATED APRIL 11, 1924

RITTER, HANS KARL, Manager, Ritter Illuminating & Mfg. Co., Ltd., Niagara Falls, N. Y.

MEMBERS ELECTED APRIL 11, 1924

BINZ, WALTER C., Engg. Dept., The United Gas Improvement Contracting Co., 1401 Arch St., Philadelphia; res., Lansdowne, Pa.

BROADHEAD, ALGERNON PERCIVAL, Supt. of Power, New York State Gas & Electric Corp., 172 Main St., Oneonta, N. Y.

DEGEN, FREDERICK I., Plant Engineer, Yosemite Lumber Co., Merced Falls, Calif.

DODSON, HARRY IRVIN, Acting Chief Engineer, Northwestern Bell Telephone Co., 19th & Douglas Sts., Omaha, Nebr.

FRANKLIN, CHARLES WHITE, Asst. to Electrical Engineer, United Electric Light & Power Co., 130 E. 15th St., New York, N. Y.

GOIN, NEWBOLD C., Supervising Field Engineer, Electrical Div., Westinghouse Elec. & Mfg. Co., 6905 Susquehanna St., Pittsburgh, Pa.

HEITZLER, ALBERT H., General Superintendent, The Ohio Public Service Co., 405 Broad St., Elyria, Ohio.

MOORE, ARTHUR DEARTH, Asst. Professor, Electrical Engineering Dept., University of Michigan, 274 W. Engineering Bldg., Ann Arbor, Mich.

REQUARDT, GUSTAV J., Member of Firm, Norton, Bird & Whitman, 1828 Munsey Bldg., Baltimore, Md.

STEIN, ADAM, Jr., Managing Engineer, Radio Dept., General Electric Co., Schenectady, N. Y.

TRANSFERRED TO GRADE OF FELLOW APRIL 11, 1924

McCANN, WILLIAM R., Electrical Engineer, Stone & Webster, Boston, Mass.

SHEPARD, FRANCIS H., Director of Heavy Traction, Westinghouse Electric & Mfg. Co., New York, N. Y.

TRANSFERRED TO GRADE OF MEMBER APRIL 11, 1924

AHLBORN, GEORGE H., Industrial Engineer, Kansas Gas & Electric Co., Wichita, Kans.

BUTCHER, WILLARD F., Senior Engineer, New York & Queens Electric Light & Power Co., Long Island City, N. Y.

ELLYSON, DOUGLAS W., Station Engineer, Kansas City Power & Light Co., Kansas City, Mo.

FLASHMAN, H. W., Sales Engineer, Westinghouse Electric International Co., Sydney, Australia.

VANDERPOLL, JAN A., Assistant Field Engineer, Westinghouse Electric & Mfg. Co., New York, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held April 7, 1924, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

BOYRER, WILLIAM CHARLES, Electrical Engineer, Public Service Commission, State of New York, New York, N. Y.

SPENCER, CLARENCE G., Engineer, McClellan & Junkersfeld, Inc., New York, N. Y.

WITHINGTON, SIDNEY, Electrical Engineer, New York, New Haven & Hartford Railroad, New Haven, Conn.

To Grade of Member

CALDERWOOD, EVERETT M., Engineer, Pacific Tel. & Tel. Co., San Francisco, Calif.
CONE, D. I., Protection Engineer, Pacific Tel. & Tel. Co., San Francisco, Calif.
DELEHANTY, WALTER J., Representative, General Electric Co., Sacramento, Calif.
DEWEY, FRED S., Assistant General Manager, Kansas City Power & Light Co., Kansas City, Mo.
IDAIL, MURRAY J., Electrical Engineer with Francis R. Weller, Washington, D. C.
MOSSAY, PAUL A., Consulting Electrical Engineer, London, England
RUHLING, T. C., Superintendent, Underground Construction, Kansas City Power & Light Co., Kansas City, Mo.
SMITH, ELMER A., Consulting Electrical Engineer, Warren & Wetmore, New York, N. Y.
STRYKER, CLINTON H., Assistant Professor of Electrical Engineering, Armour Institute of Technology, Chicago, Ill.
THORNTON, WILLIAM NELSON, LIEUT. (Junior grade) U. S. Navy, Bureau of Navigation, Navy Department, Washington, D. C.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to higher grade than Assocciate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before May 31, 1924.

Abbott, J. M., The Pacific Tel. & Tel. Co., Seattle, Wash.
Addison, E. H., Newburyport Gas & Electric Co., Newburyport, Mass.
Anderson, R. V., Jr., Neon Light Co., Brooklyn, N. Y.
Arntzen, E. D., 100 Columbia Ave., Vandergrift, Pa.
Ascroft, C., Smith, Robinson & Co., Ltd., Victoria, B. C.
Baden, S. C., Western Electric Co., Inc., Philadelphia, Pa.
Bain, G. F., Copperweld Steel Co., Rankin, Pa.
Baker, L. E., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Balteau, A. E., Michigan Telephone Co., Detroit, Mich.
Bartek, J. T., Stone & Webster, Inc., Seattle, Wash.
Beck, A. W., Kentucky Utilities, Pineville, Ky.
Beger, A. R., Delta Star Electric Co., Chicago, Ill.
Bell, C. W., Elec. Storage Battery Co. of Philadelphia, Atlanta, Ga.
Bentley, C. E., Pacific Gas & Electric Co., San Francisco, Calif.
Breisky, J. V., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Breuning, W. P., Illinois Glass Co., Bridgeton, N. J.
Broadt, P. H., Lehigh Valley Coal Co., Wilkesbarre, Pa.
Brownell, F. A., Public Service Production Co., Newark, N. J.
Bryant, C. C., Board of Water & Elec. Lt. Comm., Lansing, Mich.
Bunyan, G. A., Cornell University, Ithaca, N. Y.
Cameron, C. F., Rock Springs High School, Rock Springs, Wyoming
Carmody, J. V., New York Telephone Co., New York, N. Y.
Carter, W. L., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Chapin, B. L., Stone & Webster, Inc., Boston, Mass.
Chapman, C. C., Federal Telegraph Co., Palo Alto, Calif.
Clarke, E. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Colclesser, R. E., Tri-State College of Engg., Angola, Ind.
Conde, A. R., School of Engg. of Milwaukee, Milwaukee, Wis.
Cooney, W. H., General Electric Co., Pittsfield, Mass.
Corkran, A. G., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Coultas, F. O., Supt. of Light & Water Plant, Anthony, Kans.
Cowan, J. H., James Supply Co., Chattanooga, Tenn.
Craft, F. M., Ohio Bell Tel. Co., Cleveland, Ohio
Crammond, G. W., Western Electric Co., Inc., Cincinnati, Ohio
Crawford, R. L., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Crowder, S. R., (Member), Western Union Telegraph Co., New York, N. Y.
Culverhouse, H. A., Habirshaw Electric Cable Co., Cincinnati, Ohio
Eberwine, A. F., Ohio Bell Tel. Co., Youngstown, Ohio
Eliasen, H., New York Edison Co., New York, N. Y.
Evans, F. W., (Member), Westinghouse Elec. & Mfg. Co., New York, N. Y.
Evans, J. H., Dwight P. Robinson & Co., New York, N. Y.
Everson, W. A., Rumsey Electric Co., Philadelphia, Pa.
Finman, B., Southern New England Tel. Co., New Haven, Conn.
Fleming, T. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Forman, H. W., Jr., Western Colorado Power Co., Durango, Colo.
Fortune, C. L., Wm. T. Tilden, Jr., High School, West Philadelphia, Pa.
Fowler, F. C., New York Telephone Co., Brooklyn N. Y.
Frank, W. F., General Electric Co., Erie, Pa.
Fuller, D. W., Atchinson, Topeka, Santa Fe Railway Co., Topeka, Kans.
Gallagher, J. J., Westinghouse Elec. & Mfg. Co., Brooklyn, N. Y.
Goo, R., with Thos. E. Murray, Inc., New York, N. Y.
Gray, J. C., Pacific Tel. & Tel. Co., Portland, Ore.
Griffith, C. H., Missouri-Kansas-Texas R. R., Parsons, Kansas
Guse, R. C., Washington Water Power Co., Spokane, Wash.
Haff, A. F., New York Edison Co., New York, N. Y.
Hall, R. A., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Hardenbergh, B., The Ohio Public Service Co., Lorain, Ohio
Harding, F. J., American Tel. & Tel. Co., New York, N. Y.
Harris, C. G., The Chesapeake & Potomac Tel. Co., Richmond, Va.
Harris, S., Tech. Editor, Radiofax, Lefax Pub. Co., Philadelphia, Pa.
Hausler, E. H., Westinghouse Elec. & Mfg. Co., Denver, Colo.
Henderson, D. H., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Heim, E. F., Utah Power & Light Co., Salt Lake City, Utah
Hill, C. M., Monongahela West Penn Public Service Co., Fairmont, W. Va.
Hockenbeamer, E. F., Westinghouse Elec. & Mfg. Co., San Francisco, Calif.
Hulseman, G. D., Jos. Dixon Crucible Co., St. Louis, Mo.
Jameson, R. M., Elevator Supplies Co., Hoboken, N. J.
Johnson, H. W., 519 W. 147th St., New York, N. Y.
Johnson, J. H., Fisher Body Ohio Co., Cleveland, Ohio
Jones, C. L., Athens County Home Tel. Co., Athens, Ohio
Jones, J. W., Elec. Designer, T. E. Murray, Inc., New York, N. Y.
Jones, W. L., Public Service Co. of N. Illinois, Chicago, Ill.
Kearns, E. W., Habirshaw Electric Cable Co., Chicago, Ill.
Leaf, C. L., Electric Storage Battery Co., Kingston, Pa.
LeBow, I. V., Terrell Croft Engineering Co., St. Louis, Mo.
Lee, J. M., (Member), Westinghouse Elec. & Mfg. Co., Los Angeles, Calif.
Lefferts, B., General Instrument Corp., New York, N. Y.
LeRoy, C. A., Cornell University, Ithaca, N. Y.
Lockhart, W. S., Public Service Production Co. Newark, N. J.
Lohman, R. C., Pennsylvania Elec. Engr. Co., Scranton, Pa.
Lyons, S. A., Tri-State College, Angola, Ind.
Macdonald, A. J., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Mansfield, E. C., General Electric Co., New York, N. Y.
Martinengo, F. M., N. Y. & Queens Elec. Lt. & Pr. Co., Long Island City, N. Y.
McDavitt, J. G., The New England Tel. & Tel. Co., Boston, Mass.
McGuire, D. B., Electrical Contractor, New Berlin, N. Y.
McMackin, L. J., Pennsylvania Edison Co., Easton, Pa.
McPherson, J. D., 3rd, Pacific Gas & Electric Co., Sacramento, Calif.
Mergenthaler, E. F., New York Telephone Co., New York, N. Y.
Meyers, D. F., Kentucky & W. Virginia Power Co., Sprigg, W. Va.
Montgomery, M., Canadian Westinghouse Co., Ltd., Vancouver, B. C.
Montross, F. A., Indiana Bell Telephone Co., Indianapolis, Ind.
Mras, M. J., Duquesne Light Co., Pittsburgh, Pa.
Murray, M. J., Western Electric Co., Inc., Chicago, Ill.
Newman, R. C., Susquehanna Collieries Co., Wilkes-Barre, Pa.
Nolte, H. J., General Electric Co., Schenectady, N. Y.
Overton, R. B., Western Electric Co., Inc., Chicago, Ill.
Parino, R. Q., Philipine Refining Corp., Cebu, Cebu, P. I.
Parrott, D. F., Northern States Power Co., Minneapolis, Minn.
Payne, B. T., Alabama Power Co., Birmingham, Ala.
Pettenden, A. H., (Member), Canadian Cons. Rubber Co., Ltd., Montreal, P. Q., Can.
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Poole, H. S., Kerry & Chace, Toronto, Ont.
Puxon, E., Canadian Westinghouse Co., Ltd., Hamilton, Ont.
Ramsey, H. B., General Electric Co., Schenectady, N. Y.
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Raymond, E. P., Tri-State College, Angola, Ind.
Rennick, W. H., Price Electric Co., Cleveland, Ohio
Reutter, J., Westinghouse Elec. & Mfg. Co., Brooklyn, N. Y.
Roubicek, J., Westinghouse Elec. & Mfg. Co., Brooklyn, N. Y.
Royt, E. S., Pfister & Vogel Leather Co., Milwaukee, Wis.
Sabatke, E. G., Kentucky Utilities Co., Louisville, Ky.
Schroeder, W., The Cleveland Railway Co., Cleveland, Ohio
Searles, E. R., Public Service Electric Co., Newark, N. J.
Sepulveda, H. P., Mexican Light & Power Co., Necaxa, Puebla, Mex.
Severin-Jungman, L. J., Duquesne Light Co., Pittsburgh, Pa.

Shallenberger, J. W., Consulting Electrical Engineer, Bridgeport, Conn.
Sharp, C. S., Engg. Student, 201 S. West St., Angola, Ind.
Simmons, N. K., Kansas City Power & Light Co., Kansas City, Mo.
Smith, C. E., Vacuum Oil Co., New York, N. Y.
Smith, C. R., Des Moines Electric Co., Des Moines, Iowa
Smith, R., Pittsburgh Plate Glass Co., Zanesville, Ohio
Smith, S. A., Jr., Public Service Electric Co., Passaic, N. J.
Sonett, E., New York Edison Co., New York, N. Y.
Stewart, R. G., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Strasser, J., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Strong, J. H., Philadelphia Rapid Transit Co., Philadelphia, Pa.
Summers, S. D., Tri-State College, Angola, Ind.
Teasdale, J., British Columbia Railway Co., Vancouver, B. C.
Theis, A. R., Westinghouse Elec. & Mfg. Co., Brooklyn, N. Y.
Thomas, H. E., Interstate Commission, Washington, D. C.
Titley, R. H., Public Service Electric Co., Irvington, N. J.
Towne, H. M., General Electric Co., Pittsfield, Mass.
Townsend, W. A., Vacuum Oil Co., New York, N. Y.
Trencheny, J. T., McKenzie, Voorhes & Gmelin, New York, N. Y.
Tuttle, P. C., American Tel. & Tel. Co., Cleveland, Ohio
Updegraff, F. W., Electric Bond & Share Co., New York, N. Y.
Valldejuly, R. R., Student, Columbia University, New York, N. Y.
Vallier, J., DeB., General Electric Co., Schenectady, N. Y.
Vana, V. V., 105 Beech Ave., Flushing, N. Y.
Van Volkenburg, R., Consumers Power Co., Jackson, Mich.
Von Bernath, L., Mexican Light & Power Co., Mexico D. F., Mex.
Watson, E. W., The Pacific Tel. & Tel. Co., Los Angeles, Calif.
Weiss, S., Freed Eiseman Radio Corp., Brooklyn, N. Y.
Whitmore, P. J., General Electric Co., Schenectady, N. Y.
Whitt, H. L., Missouri Pacific Railway Co., Hoisington, Kans.
Wilson, C. B., General Electric Co., Schenectady, N. Y.
Wolfe, E. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Woodson, R. K., Kansas City Power & Light Co., Kansas City, Mo.
Total 149

Foreign

Creed, E. St.C., Tata Hydro-Electric P. S. Co., Parel, Bombay, India
de Silva, P. R. C., The Sao Paulo Tram. Lt. & Pr. Co., Ltd., Sao Paulo, Brazil, S. A.
Hancox, J. C., Borough Council, Lyttelton, N. Z.
Hiramoto, D. K., Hawaiian Sugar Co., Makaweli, Kauai, Hawaai
Holst, L., c/o Drammens Elektricitetsverk, Drammen, Norway
Juselius, H., S. Finland Interurban Telephone Co., Helsingfors, Finland
Kajii, T., Dept. of Communication, Japanese Govt., Teishinsho, Tokyo, Japan
Kennedy, H. S., International Petroleum Co., Negritis, Talara, Peru, S. A.
Meyer, W. A. R., Hengelosche Elec. & Mech. Apparaten Fabriek, Hengelo, Holland
Muniratnam, G., Tata Hydro & Co., Khopoli, Bombay, India
Oboukhoff, N. M., (Member), Russian Chinese Poly. Inst., Harbin, Manchuria, China
Packard, R. A., (Member), Ludlow Jute Co., Ltd., Calcutta, India
Scholefield, P. W., Brush Electrical Engg. Co. Ltd., Loughborough, Leicester, Eng.
Total 13

STUDENTS ENROLLED APRIL 11, 1924

18839 Ford, William J., Villanova College
18840 Meyers, Lester H., University of Alabama
18841 Dawson, S. Edward, University of Alabama
18842 Secord, Ralph E., University of New Brunswick
18843 Durboraw, I. Newton, Jr., Pennsylvania State College
18844 Brackett, Richard T., South Dakota University
18845 Makens, Clarence P., South Dakota University
18846 Baab, Harold H., South Dakota University
18847 Tilton, Russell G., Purdue University
18848 Bloye, Norman C., Purdue University
18849 Baker, Arthur W., Brooklyn Polytechnic Institute
18850 Barney, George C., University of Maine
18851 Eldridge, Tausias I., University of Pennsylvania
18852 Hallowell, Noel E., Iowa State College
18853 Levine, Samuel, Brooklyn Polytechnic Institute
18854 McLaughlin, William H., Pennsylvania State College
18855 Donaldson, Kenneth M., Rensselaer Polytechnic Institute
18856 Snyder, Reginald J., Rensselaer Polytechnic Institute
18857 Wren, Edward E., Rensselaer Polytechnic Institute
18858 Stoler, Samuel B., Pennsylvania State College
18859 Fowler, William J., University of Florida
18860 Hiscox, William L., Brooklyn Polytechnic Institute
18861 Katzer, Solomon, Columbia University
18862 Horn, John P., Alabama Polytechnic Institute
18863 Nichols, James A., Alabama Polytechnic Institute
18864 Wood, William B., Alabama Polytechnic Institute
18865 Hillemeier, Alfred K., University of Illinois
18866 Taft, George L., Washington State College
18867 Scott, George Jr., University of Arizona
18868 Rapp, Stanley B., Pennsylvania State College
18869 Smith, Paul P., Ohio Northern University
18870 Grant, Robert, Norwich University
18871 Jewett, Ulmer M., Norwich University
18872 Monahan, John H., Jr., Norwich University
18873 Van Ness, W. Darwin, Norwich University
18874 Hendricks, Roy M., Pennsylvania State College
18875 Newman, Eugene V., University of Colorado
18876 Shaver, Arthur J., University of Nevada
18877 Nemetz, Victor W., University of Wisconsin
18878 Donner, Henry F., University of Michigan
18879 Funk, Harold L., University of Illinois
18880 Rumohr, Charles G., University of Denver
18881 Lysaght, Vincent E., Mass. Institute of Technology
18882 Johnson, Lyman S., Mass. Institute of Technology
18883 Ahuga, Yog Dhiyan, University of Illinois
18884 Carlson, Ralph E., University of Arizona
18885 Keehler, Howard I., University of Southern California
18886 Slotsky, Sam J., University of South Dakota
18887 Harvey, John E., Jr., Rhode Island State College
18888 Shields, John V., Rensselaer Polytechnic Institute
18889 Baldwin, Curtis W., Montana State College
18890 Steinert, Earl E., Union College
18891 Murray, Clarence M., Jr., University of Washington
18892 Wallgren, Lloyd E., University of Washington
Total 54

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A. I. E. E. SECTIONS AND BRANCHES

See the March 1924 issue for the latest published list. The Institute now has 47 Sections and 76 Branches, a complete list of which will appear in the June issue of the JOURNAL.

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

Wires and Cables.—Bulletin, 32 pp., illustrates railroad and power installations of Okonite wires and cables. The Okonite Company, Passaic, N. J.

Ball Bearings.—Bulletin M-1, 28 pp., describes the application of ball bearings in electric motors. Gurney Ball Bearing Company, Jamestown, N. Y.

Storage Batteries.—Bulletin 12 pp., describes Edison nickel-iron-alkaline storage batteries for electric tractors. Edison Storage Battery Company, Orange, N. J.

Commutator Slotters.—Bulletin, 4 pp., describes commutator slotting devices, hand and motor driven, and commutator cement. The Martindale Electric Company, Cleveland, Ohio.

Brush Application.—A monthly publication giving information and news regarding carbon, graphite and metal graphite brush applications. Corliss Carbon Company, Bradford, Pa.

Electrical Sheets.—Bulletin, 28 pp., describes special sheets for the magnetic structure of electrical apparatus. American Sheet & Tin Plate Company, Frick Building, Pittsburgh, Pa.

Automatic Pump Control.—Bulletin, 12 pp. Describes automatic pump control for railways, docks and other public utilities. Electric Control, Ltd., Bridgeton, Glasgow, Scotland.

High Voltage Insulators.—Bulletin S. P. 1690, 56 pp. A comprehensive description of the design and manufacture of high voltage porcelain insulators. Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Electric Railway Signals.—Bulletin, 16 pp., describes a new signal of the overhead trolley type for electric railways. American Insulating Machinery Company, Fairhill & Huntingdon Streets, Philadelphia, Pa.

Variable Speed Motor.—Bulletin 301, describes the Kimble variable speed motor especially designed for testing of automobile generators. Kimble Electric Company, 634 N. Western Avenue, Chicago, Ill.

Brass Melting Furnaces.—Bulletin, 8 pp., describes the economies effected by brass melting in electric furnaces, and illustrates a number of such installations. The Detroit Electric Furnace Company, Detroit, Mich.

Northern White Cedar Poles.—Bulletin, 12 pp., on the advantages of Northern White Cedar Poles for transmission purposes; includes official pole specifications. Northern White Cedar Association, Lumber Exchange, Minneapolis, Minn.

Emmet Mercury Vapor Process.—Bulletin Y-1910, 8 pp., deals principally with the mercury boiler installed at the Dutch Point plant of the Hartford Electric Light Company, Connecticut. General Electric Company, Schenectady, N. Y.

Chains and Conveyors.—Catalog 210, 512 pp., listing the entire line of Rex chains and conveyors. One of the features of the new book is that weights and complete dimensions are shown for practically every item listed. The Chain Belt Company, Milwaukee, Wis.

Solenoid Relay.—Bulletin describing a solenoid relay for automatically controlling lighting of safety traffic lights from the main power station, simultaneously with the series street lights. Eldredge Electric Manufacturing Company, Springfield, Mass.

Time Switches.—Bulletin, A3, 4 pp., illustrates a number of the Sauter types of self winding electric time switches ranging from 2 to 300 amperes. 110-250 volts; and 25 and 50 amperes, 3300-6600 volts. R. W. Cramer & Company, Inc., 136 Liberty Street, New York, N. Y.

Speed Reducing Transmissions.—Bulletin 8, 112 pp., describes spur and worm gear speed reducing transmissions and illustrates their adaption to requirements of many industries. D. O. James Manufacturing Company, 1114 W. Monroe Street, Chicago, Ill.

Electrical Slate.—Bulletin, 92 pp., "Slate for Electrical Uses." Outlines the development, uses and testing of slate for electrical applications; quarrying and production, results of tests; proper mounting; illustrations of applications and other information. The Structural Slate Company, Pen Argyl, Pa.

Static Condensers.—Bulletin 1670, 20 pp., "Static Condensers for Power Factor Correction." The method of selecting the proper corrective device for power factor is carefully analyzed, and the fields of application of synchronous and static condensers set forth in diagrammatic form. The Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa.

Motors and Generator Sets.—New bulletins have been issued as follows: Bulletin D, d-c. motors, 1 to 100 h. p.; Bulletin A, squirrel cage, a-c. motors, 1 to 100 h. p.; Bulletin A D, motor-generator sets, 1 to 75 kw.; Bulletin P, electroplating generators and motor-generator sets, 25 to 15,000 amperes. Chandeysson Electric Company, 4092 Bingham Ave., St. Louis, Mo.

High Voltage Equipment.—A series of bulletins bound in a handsome leather binder describing the S & C line of high voltage protective, switching and testing equipment. Among the more important apparatus included in this line are lightning arresters, disconnecting switches, high voltage fuses, choke coils, indoor and outdoor bus supports and fuse cutouts. Schweitzer & Conrad, Inc., 4431 Ravenswood Ave., Chicago, Ill.

Protective Relay Systems.—Bulletin Ga-240, 32 pp., "Notes on Protective Gear," giving technical information on various systems of automatic protection for electrical machinery, switches and lines. The protection of alternators, transformers, cables and overhead lines, and switching equipment is discussed and various possible dangerous conditions are outlined, together with the possible relay schemes which would operate to prevent or limit damage to equipment. The types of protection include overload, reverse power, balanced-relay systems of several kinds, etc. The information on cable and line protection is quite complete and covers various schemes making use of balanced relays and split-conductor cables. Ferranti Limited, Hollinwood, Lancashire, England.

NOTES OF THE INDUSTRY

Century Electric Company, St. Louis, Mo.—The Chicago office of the company has been changed from 56 W. Randolph Street to R.1931-3, 160 N. LaSalle Street.

General Electric Company, Schenectady, N. Y.—Orders received for three months ending March 31, total $73,487,903 according to Gerard Swope, President. This is a decrease of 8% over the first quarter of 1923, when orders totalled $80,010,045.

Western Electric Business Grows.—A volume of business well in excess of last year is shown in figures for the first quarter of 1924, just made public by the Western Electric Company. Billings for the first three months of 1924 amounted to $68,246,000 exceeding by $16,480,000 the total for the corresponding period of 1923. Orders booked were $80,591,000, or $12,793,000 more than orders received in the first quarter of last year.

The American Transformer Co., Newark, N. J., has purchased the building and land adjoining its present plant at 174-182 Emmet Street. Additional manufacturing space to the extent of 10,000 square feet is thus available, and it will all be needed to take care of the production of the "AmerTran" radio line, as well as the increasing special transformer business.